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APOLLO 9 SLA PANEL JETTISON
SEPARATION AND RECONTACT
ANALYSIS



Flight Analysis Branch

MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS



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APOLLO 9 SLA PANEL JETTISON SEPARATION
AND RECONTACT ANALYSIS

By M. L. Williamson and C. W. Fraley
Flight Analysis Branch

February 24, 1969

MISSION PLANNING AND ANALYSIS DIVISION
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APOLLO 9 SLA PANEL JETTISON

SEPARATION AND RECONTACT ANALYSIS

By M. L. Williamson and C. W. Fraley

1.0 SUMMARY

An analysis was conducted to determine if the jettison of the four spacecraft/LM adapter (SLA) panels would create any potential recontact problems with the spacecraft (SC) on the nominal Apollo 9 mission, or for launch phase aborts or orbital aborts. The results of the analysis indicate that jettison of the four SLA panels with a jettison velocity (ΔV) equal to 11 ± 3 fps and at an attitude of $110 \pm 20^\circ$ with respect to the S-IVB +X-axis assures adequate separation clearances during the nominal, launch abort, and orbital abort phases of the mission with the exception of the retrograde SPS mode III abort region. These results are based on a stable and controlled launch vehicle at the time of command and service modules (CSM) separation and panel jettison.

In the mode III region, the in-plane retrograde service propulsion system (SPS) deorbit maneuver, which is performed 2 minutes 5 seconds after abort initiation, results in the spacecraft flying near or between the four jettisoned SLA panels approximately 2 to 3 minutes after abort initiation. Relative motion indicates that a potential recontact situation develops between the spacecraft and panel 2 (the pitched-down panel) immediately after the initiation of the abort burn. The minimum displacement of panel 2 varies from zero to 800 ft below the spacecraft and occurs for an abort which is initiated during approximately the first 30 seconds of the SPS retrograde mode III region. The other three panels exhibit adequate separation clearance for all mode III abort regions. The potential recontact problem with the spacecraft is based on the presently defined mode III sequencing and on the assumptions and inputs as defined in this internal note.

2.0 INTRODUCTION

The jettison of the four SLA panels will occur at CSM/S-IVB separation immediately after panel deployment. The jettison of the panels is a part of the CSM/S-IVB separation sequence and, therefore, will occur for the nominal mission and for all launch phase aborts and orbital aborts on Apollo 9 with the exception of mode I. Aborts initiated in the mode I region are launch escape tower jettisons of the command module (CM) from the service module (SM); therefore, no panel deployment or jettison occurs.

The analysis performed in this study is based on SLA panel jettison attitudes and resultant jettison velocities which encompass the higher panel deployment rates (60 deg/sec to 74 deg/sec) observed in postflight analysis of Apollo 7 (ref. 1). The higher opening rate (74 deg/sec) could result in the jettison of the panels at a maximum attitude of 130° (measured with respect to the S-IVB +X-axis) at a maximum resultant velocity of 14 fps. Minimum values of jettison attitude and velocity remain at their previous levels of 90° and 8 fps, respectively (ref. 2).

This analysis considers jettison attitudes of $110 \pm 20^\circ$ and resultant jettison velocities of 11 ± 3 fps. The SLA panels weigh an average of 622 lb (ref. 3), have a projected reference area of 239 ft^2 (ref. 2), and have a tumbling drag coefficient of 1.7 (ref. 4).

3.0 COORDINATE SYSTEMS

3.1 S-IVB Attitudes and Panel Jettison Attitudes

The primary factor that affects the relative motion of the SLA panels is the direction in which they are jettisoned with respect to the inertial velocity vector of the S-IVB at the time of jettison. This direction is determined by the jettison attitude (θ) of the panels and by the attitude of the S-IVB (ϕ_v) with respect to the inertial velocity (v_i). Jettison attitudes are measured in the S-IVB pitch plane for the upper and lower panels [fig. 1(a)] and in the S-IVB yaw plane for the two lateral panels [fig. 1(b)].

3.2 Panel Identification

For identification and simplification, the four SLA panels are referred to as panels 1, 2, 3, or 4 throughout this report. The pitched-up (+Z) and pitched-down (-Z) panels are numbered 1 and 2, respectively [fig. 1(a)]. The yawed-right (+Y) and yawed-left (-Y) panels are numbered 3 and 4, respectively [fig. 1(b)]. A front view of all four panels is presented in figure 1(c).

3.3 Relative Motion Coordinates

The relative motion figures presented in this report were generated in the inertial azimuth coordinate system. The origin of this system is located at the origin of the body coordinate system of the reference vehicle. In this report, the spacecraft is the reference vehicle and is located at the origin of the figures so that the curves represent the relative motion of the panels about the spacecraft. Down-range distance (X) lies along the intersection of the orbital and local horizontal (geodetic) planes and is positive in the direction of the velocity vector [fig. 1(a)]. Radial distance is indicated as either Y or Z displacement. Lateral (cross-range) displacement (Y), is measured in the local horizontal plane, normal to X and positive to the right [fig. 1(b)]. Vertical displacement (Z) lies in the orbital plane normal to X and is positive up [fig. 1(a)].

4.0 LAUNCH PHASE

The launch phase aborts are analyzed by use of a panel jettison $\Delta V = 11 \pm 3$ fps for attitudes of $\theta = 110 \pm 20^\circ$. Three cases (early, middle, and late) were evaluated for each of the modes II, III, and IV abort regions. Mode I aborts are tower jettisons with the CM separating from the SM; therefore, no panel deployment or jettison occurs.

4.1 Mode II Aborts

The mode II abort region begins when the launch escape tower (LET) is jettisoned and ends when the CM full-lift landing point reaches the Atlantic Discrete Recovery Area (ADRA). After initiation of a mode II abort, the CSM separates from the S-IVB and, after CM/SM separation and entry preparation, flies a full-lift entry into the Atlantic Continuous Recovery Area (ACRA). No CSM SPS burns are incorporated in a mode II abort. The initial conditions at SLA panel jettison (CSM/S-IVB separation) for the early, middle, and late mode II abort regions are presented in tables I, II, and III (ref. 5). The abort sequence used for the mode II analysis (ref. 6) is presented in the following table.

MODE II ABORT SEQUENCE

Event ^a	Time from abort initiation, min:sec
Initiation of abort	00:00
Beginning of CSM direct ullage	00:00
CSM/S-IVB physical separation	00:03
Jettison of SLA panels, $\Delta V = 11 \pm 3$ fps	00:03
Initiation of CSM +X translation	00:03
Termination of CSM +X translation, $\Delta V = 5.0$ fps	00:24
Orientation to CM entry attitude	00:24
CM/SM separation	b00:84
Full-lift flight to landing	00:84

^aEvents grouped together with only one time value take place at approximately the same time.

^bThe three items associated with this value are assumed to be complete within 1 minute.

Analysis for mode II aborts indicates that the jettisoned SLA panels will not result in any eventual recontact problems. Relative motions of the SLA panels with respect to the spacecraft (figs. 2 and 3) reveal that the panels will remain well behind the spacecraft and will continue to increase in separation range during any mode II abort.

4.2 Mode III Aborts

The mode III abort procedure consists of performing an inertially-fixed SPS retrograde burn after CSM/S-IVB separation and a CM half-lift entry to land in the ADRA. To effect safe water landings in ADRA, large SPS burns are required during late mode III aborts. This situation is not desirable because, when it occurs, the spacecraft landing point moves westward across Africa during the burn, and a premature shutdown could result in a land landing. Therefore, the mode III abort is not considered a prime operating procedure, and a mode IV contingency orbit insertion (COI) will be used when possible.

The initial conditions (ref. 5) at SLA panel jettison (CSM/S-IVB separation) for early, middle, and late mode III aborts are presented in tables IV, V, and VI. The abort sequence used in the mode III analysis (ref. 6) is presented in the following table.

MODE III ABORT SEQUENCE

Event ^a	Time from abort initiation, min:sec
Initiation of abort	00:00
Initiation of CSM direct ullage	
CSM/S-IVB physical separation	
Jettison of SLA panels, $\Delta V = 11 \pm 3$ fps	00:03
Termination of ullage, beginning of +X translation	
Termination of CSM +X translation, $\Delta V = 5.0$ fps	00:24

^aEvents grouped together with only one time value take place at approximately the same time.

MODE III ABORT SEQUENCE - Concluded

Event ^a	Time from abort initiation, min:sec
Initiation of CSM SPS deorbit burn (SPS deorbit burn attitude as shown in fig. 4)	02:05
Termination of deorbit burn for early mode III, $\Delta V = 146.3$ fps, $\Delta t = 13.0$ sec (ref. 7)	02:18.0
Termination of deorbit burn for middle mode III, $\Delta V = 996.2$ fps, $\Delta t = 84.8$ sec (ref. 7)	03:29.8
Termination of deorbit burn for late mode III, $\Delta V = 1730.7$ fps, $\Delta t = 142.3$ sec (ref. 7)	04:27.3
CM/SM separation at deorbit burn attitude	end of deorbit burn
Orientation to CM entry attitude	+ 01:00
Full-lift flight to 0.2g, then banking of CM 55° S for half-lift to landing	

The mode III abort analysis establishes a potential recontact situation because of the retrograde SPS maneuver performed to deorbit the CSM. Relative motion for panel 2 and the other three panels was examined for $\theta = 110 \pm 20^\circ$ and $\Delta V = 11 \pm 3$ fps for early, middle, and late mode III aborts. The data are presented in figures 5 and 6.

The relative motion of panel 2 indicates that its minimum separation displacement [zero to 800 ft for $\theta = -130^\circ$ and -90° , respectively, fig. 5(a)] will occur for a jettison ΔV of 8 fps at approximately 25.0 seconds after SPS ignition. This is early in the mode III region (g.e.t. = 600 sec).

^aEvents grouped together with only one time value take place at approximately the same time.

If the jettison ΔV is increased [fig. 6(a)] or if an abort is initiated later in the mode III region [figs. 5(b), 5(c), 6(a) through 6(c)], greater separation displacement below the spacecraft will result for panel 2. The relative motion of panel 1 indicates that, for the simulated conditions, panel 1 will always pass above the CSM, with a minimum clearance of 1800 ft [fig. 5(a)]. Panels 3 and 4 are yawed and jettisoned out of plane with adequate cross-range and vertical displacement for all cases [figs. 5(d) through 5(f) and 6(d) through 6(f)].

The primary conclusions which can be drawn from the mode III abort SLA panel analysis are that (1) a retrograde SPS deorbit burn performed at 2 minutes 5 seconds after abort initiation will result in a potential recontact problem of the CSM with panel 2, and (2) that the potential of a recontact with a SLA panel decreases as the ground elapsed time of the mode III abort initiation increases or as the panel jettison ΔV increases.

Non-SPS mode III aborts are similar to mode II aborts except that the CM flies a half-lift entry in mode III instead of a full-lift entry. A half-lift entry profile tends to increase separation ranges; therefore, mode II analysis and relative motion is applicable.

4.3 Mode IV Aborts

The mode IV abort procedure incorporates a posigrade SM SPS burn to establish a safe orbit condition that is defined as a CSM perigee altitude equal to or greater than 75 n. mi. The mode IV abort region overlaps the modes II and III abort boundaries and will be used as the prime mode of operation whenever the capability exists to achieve a contingency orbit insertion (COI). The initial conditions at SLA panel jettison (CSM/S-IVB separation) for early, middle, and late mode IV aborts are presented in tables VII, VIII, and IX (ref. 5). The abort sequence used in the mode IV analysis (ref. 6) is presented in the following table.

MODE IV ABORT SEQUENCE

Event ^a	Time from abort initiation, min:sec
Initiation of abort	00:00
Initiation of CSM direct ullage	
CSM/S-IVB physical separation	
Jettison of SLA panels, $\Delta V = 11 \pm 3$ fps	00:03
Termination of ullage, initiation of +X translation	
Termination of CSM +X translation, $\Delta V = 5.0$ fps	00:24
Initiation of CSM COI burn for 75-n. mi. perigee altitude (SPS burn attitude as shown in fig. 8)	02:05
Termination of COI burn for early mode IV, $\Delta V = 2215.3$ fps, $\Delta t = 177.7$ sec (ref. 7)	05:02.7
Termination of COI burn for middle mode IV, $\Delta V = 1150.9$ fps, $\Delta t = 97.2$ sec, ref. 7)	03:42.2
Termination of COI burn for late mode IV, $\Delta V = 120.8$ fps, $\Delta t = 10.7$ sec (ref. 7)	02:15.7

The mode IV abort analysis indicates that adequate separation ranges are achieved by the SLA panels for any mode IV abort where jettison occurs at $\theta = 110 \pm 20^\circ$ and $\Delta V = 11 \pm 3$ fps.

^aEvents grouped together with only one time value take place at approximately the same time.

The relative motions of the pitched panels and the yawed panels are presented in figures 7 and 9. The figures indicate that the panels will separate behind and below the spacecraft. The panels for all mode IV aborts will deorbit while the CSM remains in orbit; therefore, no eventual recontact problems are present. Separation ranges continue to increase throughout the deorbit period.

A note of interest is the relative motion for the late mode IV case. In this case, the four panels will initially move behind the spacecraft, but because of the relatively small COI burn ($\Delta V = 120.8$ fps), the panels will pass below (approximately 120 000 ft) and ahead of the CSM. This differs from the other mode IV cases in which the panels consistently remain behind the SC.

5.0 ORBITAL ABORTS

The orbital abort sequence includes an SPS retrograde deorbit maneuver; but unlike mode III aborts, it delays the maneuver for 20 minutes and incorporates +X translation of the CSM during this period to maximize separation clearances. Such a procedure is not possible during a mode III abort, because time from abort initiation to entry interface (300 000 ft) is considerably less than is needed to perform the delayed SPS burn sequence.

For the Apollo 9 mission, the CSM/LM/S-IVB is inserted into a 103-n. mi. near-circular orbit. Therefore, the relative motions of the jettisoned SLA panels with respect to the spacecraft essentially are independent of the time the orbital abort is initiated. For this analysis, the initial conditions chosen were near CSM/S-IVB nominal insertion and are presented in table X (ref. 5).

Approximately 20 seconds after insertion, the CSM/LM/S-IVB is maneuvered to a posigrade local horizontal (LH) attitude. The configuration remains in this attitude, unless a crew member manually changes it, until approximately 9 minutes prior to nominal CSM/S-IVB separation, at which time the S-IVB begins orientation to the transposition and docking attitude. Therefore, should an orbital abort become necessary, the CSM/LM/S-IVB most probably would be in a local horizontal posigrade attitude.

For the Apollo 9 mission, two procedures for performing an orbital abort prior to nominal separation are being considered. Both of these procedures are considered in this analysis and are referred to as the posigrade orbital abort or the retrograde orbital abort. The retrograde orbital abort, performed manually by the crew, orients the CSM/LM/S-IVB from its posigrade LH attitude to a retrograde, heads-up, horizon monitor attitude with the +X-axis aligned 31.7° below the line of sight (LOS) to the horizon. The CSM is then separated from the S-IVB with a ΔV of 5 fps and is deorbited by an SPS abort burn approximately 20 minutes later. Analysis for this method of orbital abort is based on the following sequence.

RETROGRADE ORBITAL ABORT SEQUENCE

Event ^a	Time from abort initiation, min:sec
Initiation of abort Manual orientation by the crew of the CSM/LM/S-IVB to retrograde, heads-up, horizon monitor at- titude (attitude as shown in fig. 4)	00:00
CSM/S-IVB physical separation, initiation of +X translation	
Termination of +X translation, $\Delta V = 5.0$ fps	00:23
Beginning of CSM coast	
End of coast	
Initiation of SPS deorbit burn for 30-n. mi. perigee altitude (attitude as shown in fig. 4)	20:00
Termination of SPS deorbit, $\Delta V \approx 188.5$ fps	20:16.7

^aEvents grouped together with only one time value take place at approximately the same time.

For the posigrade orbital abort sequence, the crew does not change the local horizontal attitude of the CSM/LM/S-IVB. Analysis for this type of orbital abort is based on the following sequence.

POSIGRADE ORBITAL ABORT SEQUENCE

Event ^a	Time from abort initiation, min:sec
Initiation of abort	
CSM/S-IVB physical separation	00:00
Initiation of +X translation	
Termination of +X translation	00:21
Beginning of CSM coast	
End of coast	
Initiation of +X translation, retro-grade attitude (attitude as shown in fig. 4)	00:51
Termination of +X translation	
Beginning of coast	01:21
Initiation of SPS deorbit burn for 30-n. mi. perigee altitude (attitude as shown in fig. 4)	20:00
Termination of SPS deorbit, $\Delta V = 192.8$ fps	20:17

The jettison of the SLA panels at any attitude $\theta = 110 \pm 20^\circ$ and at a $\Delta V = 11 \pm 3$ fps presents no recontact problems when either of the two orbital abort sequences is executed. This conclusion is based on initiation of the SPS abort burn at 20 minutes after abort initiation (CSM/S-IVB separation). Note in the relative motion plots (figs. 10 through 13) that an earlier or later performance of the burn may lead to a potential recontact situation.

^aEvents grouped together with only one time value take place at approximately the same time.

For the retrograde orbital abort case, relative motions of the panels (figs. 10 and 11) indicate that adequate separation clearance will be available as the CSM deorbits. Panel 1 will initially be jettisoned below the spacecraft and will then pass ahead of and above the spacecraft [figs. 10(a) and 11(a)], but with sufficient displacement to preclude any recontact. Panel 2 will be jettisoned behind and above the spacecraft and will remain above the spacecraft during CSM deorbit. Panels 3 and 4 will obtain sufficient out-of-plane components to prevent recontact (minimum 3000 ft), and vertical displacement continually increases during CSM deorbit.

Relative motions indicate no recontact problems (figs. 12 and 13) for an orbital abort initiated in the posigrade local horizontal attitude. Panel 1 will be jettisoned above and behind the spacecraft, while panel 2 will pass below and ahead of the spacecraft [figs. 12(a) and 13(a)]. Panels 3 and 4 will pass above the CSM during deorbit with a minimum range clearance of 5000 ft. For either the retrograde or the posigrade orbital abort cases, no eventual recontact problems exist because all panels remain in orbit while the CSM deorbits.

6.0 NOMINAL SLA PANEL JETTISON

Jettison of the SLA panels under nominal conditions (table X, fig. 6) was simulated in this analysis for $\theta = 110 \pm 20^\circ$ and $\Delta V = 11 \pm 3$ fps, and no recontact problems were present. Relative motions of the panels (figs. 14 and 15) indicate that panel 1 will be jettisoned behind the spacecraft and will then pass well below the spacecraft, to remain below and ahead of the CSM throughout the remainder of its orbital lifetime. The panels are expected to deorbit between 3.5 and 5.5 hours after CSM/S-IVB separation; therefore, no eventual recontact problems exist. Panel 2 will be jettisoned below the CSM and will pass ahead of the CSM with adequate separation clearance [figs. 14(a) and 15(a)]. Although an apparent recontact situation is indicated for panel 4 [figs. 14(b) and 15(b)], sufficient vertical displacement is generated to preclude recontact [figs. 14(c) and 15(c)].

7.0 CONCLUSION

The nominal mission, launch abort phase, and orbital abort phase analyses presented in this report indicate that jettison of the four SLA panels at an attitude of $\theta = 110 \pm 20^\circ$ from the S-IVB +X-axis and at a $\Delta V = 11 \pm 3$ fps assures adequate separation displacement from the spacecraft for all Apollo 9 mission phases with the exception of the beginning of the SPS retrograde mode III region. If an abort were to be initiated within the first 30 seconds of the SPS mode III region, there exists a potential recontact situation between the pitched-down panel (panel 2) and the spacecraft [fig. 5(a)].

The mode III abort is not a prime operating procedure and will be required only if it is not possible to use the COI (mode IV abort). Based on the preceding statement and on the fact that potential recontact exists for only 30 seconds during the SPS mode III region, the identified potential recontact problems are not considered serious. However, it is reemphasized that the analysis of this report is based on CSM/S-IVB separation and panel jettison that occurs under stable (nontumbling) and controlled conditions. Should this not be the case, then relative motions of the SLA panels and of the CSM would be significantly altered, and the conclusions presented here would not necessarily be valid. Analyses for aborts initiated under tumbling conditions will be published in the Apollo 9 Separation and Recontact Analysis Summary Document (ref. 8).

The conclusion that no recontact problems are present for orbital aborts is based on the analyzed sequences (section 5.0) where the SPS deorbit burn is executed 20 minutes after abort initiation (CSM/S-IVB separation) with the CSM in the retrograde, heads-up, horizon monitor attitude (fig. 4). Execution of the burn earlier or later or in a different attitude may lead to a potential recontact situation.

TABLE I.- EARLY MODE II ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	195.9
Inertial velocity, V_i , fps	9 654.2
Inertial flight-path angle, γ_i , deg	14.39
Inertial azimuth, Ψ_i , deg	75.51
Geodetic latitude, ϕ_d , deg	29.1
Longitude, λ , deg	-78.9
Altitude, h, ft	318 487.0
S-IVB attitude ^a	
Pitch, ϕ_p , deg	-68.8
Yaw, ϕ_y , deg	-7
Roll, ϕ_r , deg	0.0

^aS-IVB attitudes in tables I through X are referenced to an earth-centered, inertial plumbline coordinate system defined at guidance reference release (GRR).

TABLE II.- MIDDLE MODE II ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	350.0
Inertial velocity, V_i , fps	13 803.6
Inertial flight-path angle, γ_i , deg	3.53
Inertial azimuth, Ψ_i , deg	77.3 ⁴
Geodetic latitude, ϕ_d , deg	30.2
Longitude, λ , deg	-74.3
Altitude, h, ft	561 268.8
S-IVB attitude	
Pitch, ϕ_p , deg	-77.3
Yaw, ϕ_y , deg	0.2
Roll, ϕ_r , deg	0.0

TABLE III.- LATE MODE II ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	600.0
Inertial velocity, V_i , fps	24 375.5
Inertial flight-path angle, γ_i , deg	.09
Inertial azimuth, ψ_i , deg	84.50
Geodetic latitude, ϕ_d , deg	32.3
Longitude, λ , deg	-60.4
Altitude, h, ft	629 444.2
S-IVB attitude	
Pitch, ϕ_p , deg	-105.7
Yaw, ϕ_y , deg	0.3
Roll, ϕ_r , deg	0.0

TABLE IV.- EARLY MODE III ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	600.0
Inertial velocity, V_i , fps	24 375.5
Inertial flight-path angle, γ_i , deg	. . . -0.09
Inertial azimuth, ψ_i , deg 84.50
Geodetic latitude, ϕ_d , deg 32.3
Longitude, λ , deg -60.4
Altitude, h, ft 629 444.2
S-IVB attitude	
Pitch, ϕ_p , deg -105.7
Yaw, ϕ_y , deg 0.3
Roll, ϕ_r , deg 0.0

TABLE V.- MIDDLE MODE III ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	632.0
Inertial velocity, V_i , fps	25 109.9
Inertial flight-path angle, γ_i , deg	-.08
Inertial azimuth, ψ_i , deg	85.76
Geodetic latitude, ϕ_d , deg	32.5
Longitude, λ , deg	-58.1
Altitude, h, ft	628 227.5
S-IVB attitude	
Pitch, ϕ_p , deg	-106.6
Yaw, ϕ_y , deg	-0.5
Roll, ϕ_r , deg	0.0

TABLE VI.- LATE MODE III ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	659.3
Inertial velocity, V_i , fps	25 567.7
Inertial flight-path angle, γ_i , deg . . .	0.01
Inertial azimuth, ψ_i , deg	86.96
Geodetic latitude, ϕ_d , deg	32.6
Longitude, λ , deg	-55.9
Altitude, h , ft	627 947.4
S-IVB attitude	
Pitch, ϕ_p , deg	-106.5
Yaw, ϕ_y , deg	0.4
Roll, ϕ_r , deg	0.0

TABLE VII.- EARLY MODE IV ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	572.0
Inertial velocity, V_i , fps	23 744.6
Inertial flight-path angle, γ_i , deg	0.04
Inertial azimuth, ψ_i , deg	83.40
Geodetic latitude, ϕ_d , deg	32.1
Longitude, λ , deg	-62.3
Altitude, h , ft	629 738.3
S-IVB attitude	
Pitch, ϕ_p , deg	-104.6
Yaw, ϕ_y , deg	0.4
Roll, ϕ_r , deg	0.0

TABLE VIII.- MIDDLE MODE IV ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	615.0
Inertial velocity, v_i , fps	24 726.4
Inertial flight-path angle, γ_i , deg	-0.11
Inertial azimuth, ψ_i , deg	85.11
Geodetic latitude, ϕ_d , deg	32.4
Longitude, λ , deg	-59.3
Altitude, h, ft	628 859.1
S-IVB attitude	
Pitch, ϕ_p , deg	-106.2
Yaw, ϕ_y , deg	0.1
Roll, ϕ_r , deg	-0.5

TABLE IX.- LATE MODE IV ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	655.0
Inertial velocity, V_i , fps	25 567.7
Inertial flight-path angle, γ_i , deg	0.01
Inertial azimuth, Ψ_i , deg	86.77
Geodetic latitude, ϕ_d , deg	32.6
Longitude, λ , deg	-56.3
Altitude, h, ft	627 929.4
S-IVB attitude	
Pitch, ϕ_p , deg	-106.5
Yaw, ϕ_y , deg	0.0
Roll, ϕ_r , deg	0.9

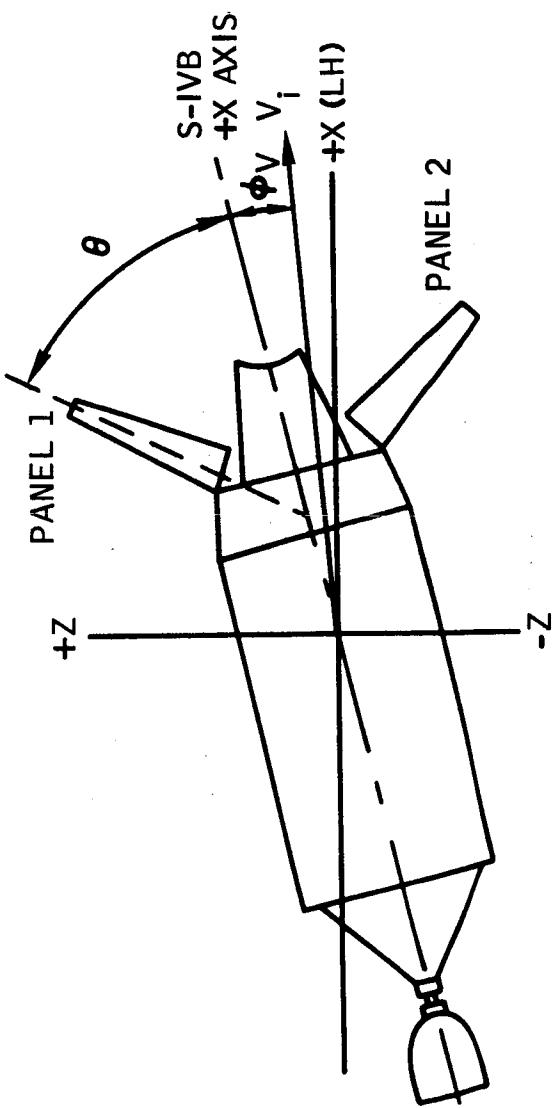
TABLE X.- ORBITAL ABORT CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	696.0
Inertial velocity, v_i , fps	25 568.2
Inertial flight-path angle, γ_i , deg	0.00
Inertial azimuth, ψ_i , deg	85.55
Geodetic latitude, ϕ_d , deg	32.7
Longitude, λ , deg	-53.1
Altitude, h , ft	628 055.2
S-IVB attitude ^a	

^aTwo S-IVB attitudes were simulated; discussion is presented under section 5.0.

TABLE XI.- NOMINAL CONDITIONS AT PANEL JETTISON

Time, sec g.e.t.	9 912.0
Inertial velocity, V_i , fps	25 559.0
Inertial flight-path angle, γ_i , deg	0.023
Inertial azimuth, Ψ_i , deg	57.5
Geodetic latitude, ϕ_d , deg	-2.6
Longitude, λ , deg	156.6
Altitude, h , ft	641 723.0
S-IVB attitude with respect to local horizontal	
Pitch, ϕ_p , deg	17.6
Yaw, ϕ_y , deg	15.5
Roll, ϕ_r , deg	00.0



$x(LH)$ DOWN/RANGE DISPLACEMENT (LOCAL HORIZONTAL)

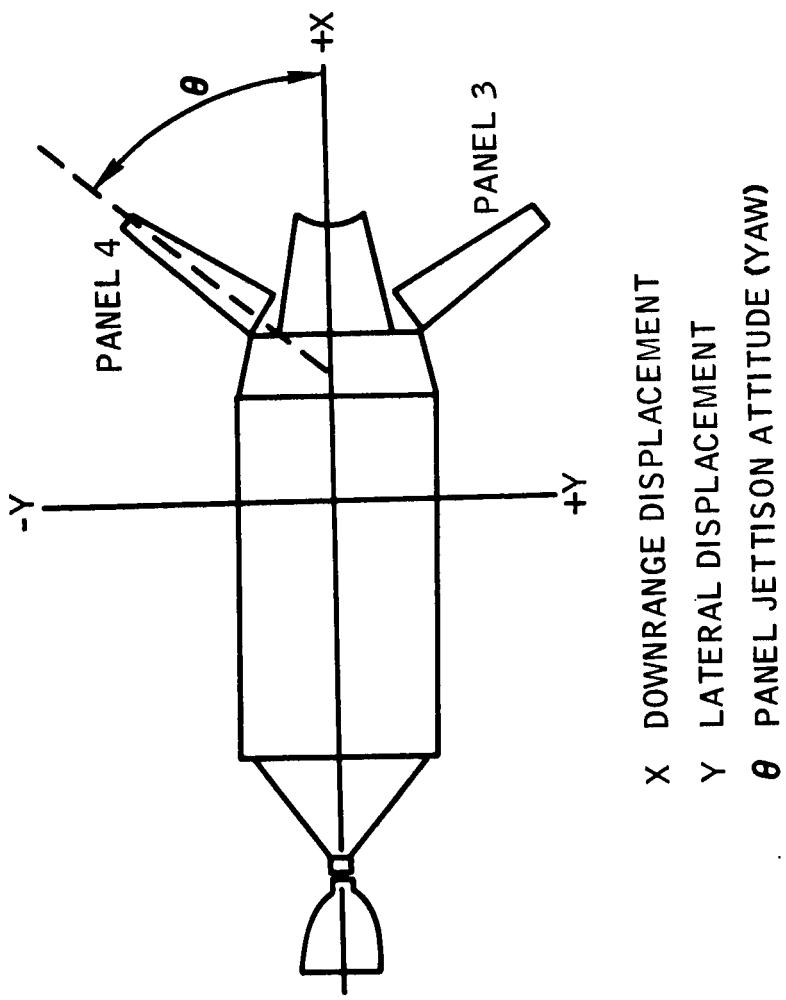
z VERTICAL DISPLACEMENT

ϕ_V S-IVB ATTITUDE WITH RESPECT TO v_i

θ PANEL JETTISON ATTITUDE (PITCH)

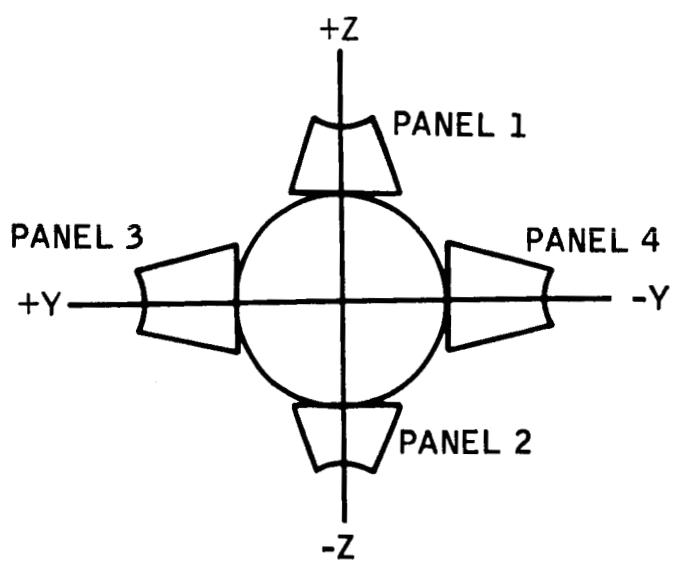
(a) Pitched panels ($X-Z$ plane).

Figure 1.- S-IVB and SLA panel attitude identification.



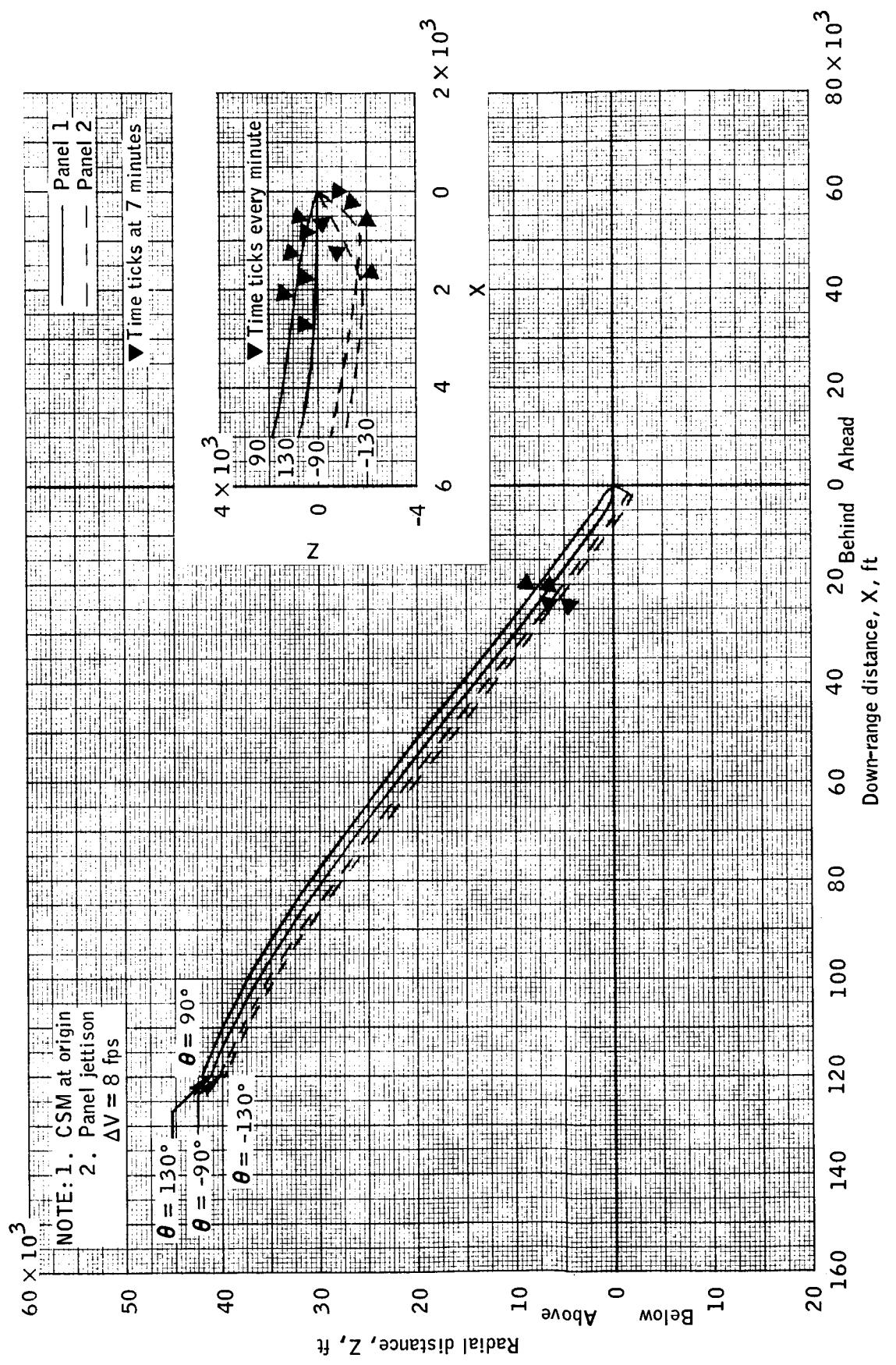
(b) Yawed panels (X - Y plane).

Figure 1.- Continued.



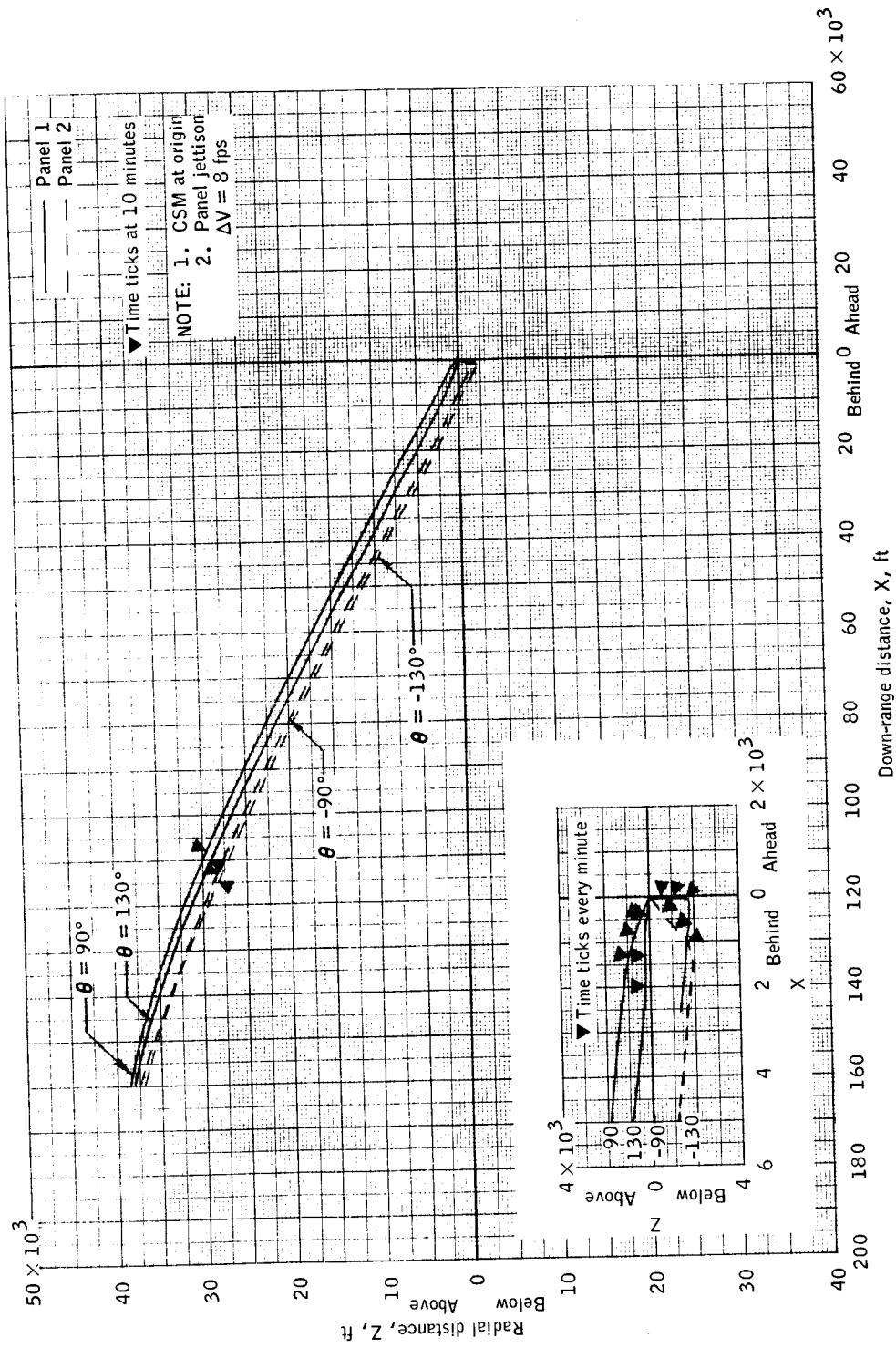
(c) Front view (Y-Z plane).

Figure 1.- Concluded.



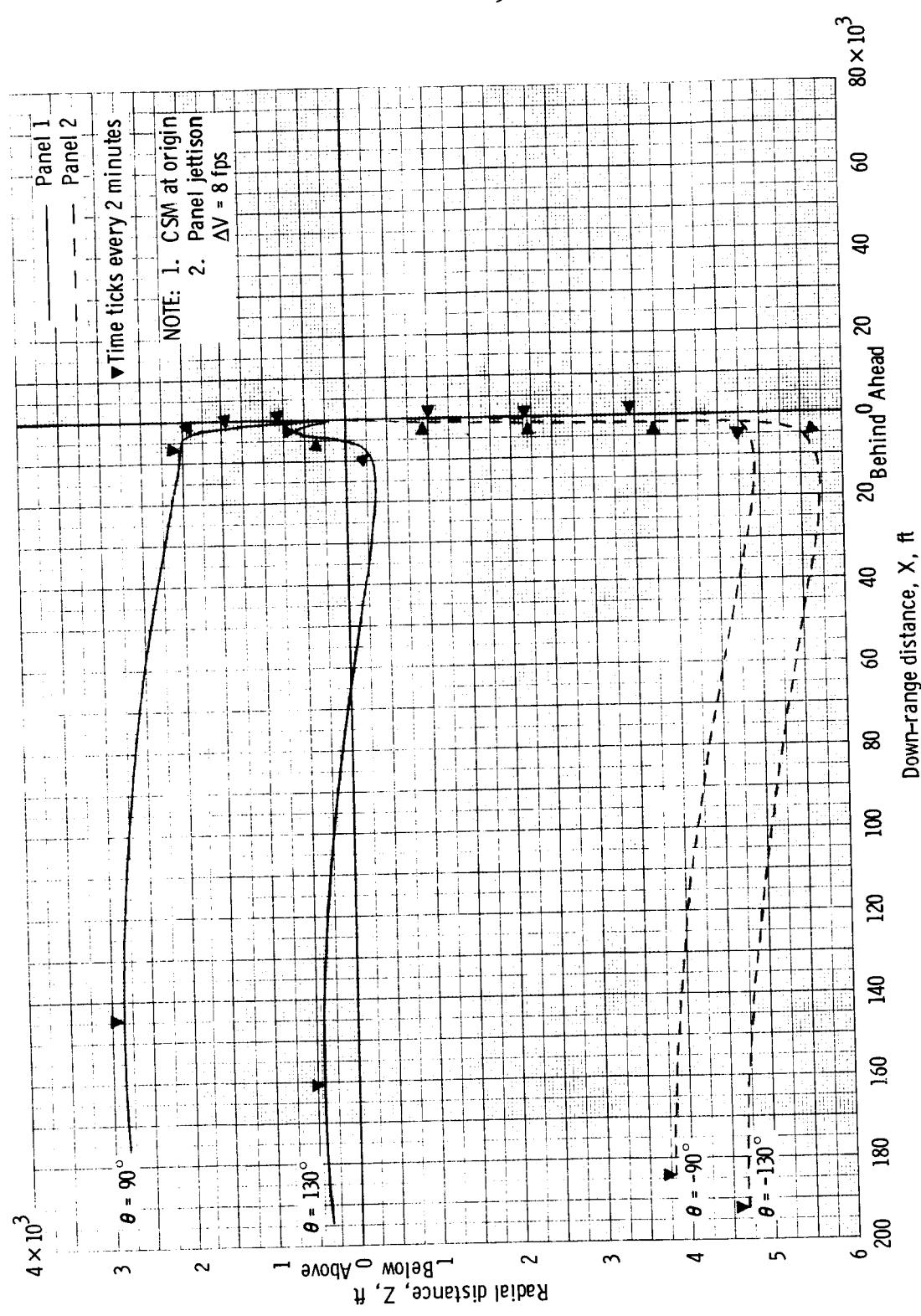
(a) Pitched panels for early mode II.

Figure 2.- SLA panels relative motion for mode II aborts, $\Delta V = 8 \text{ f/s}$.



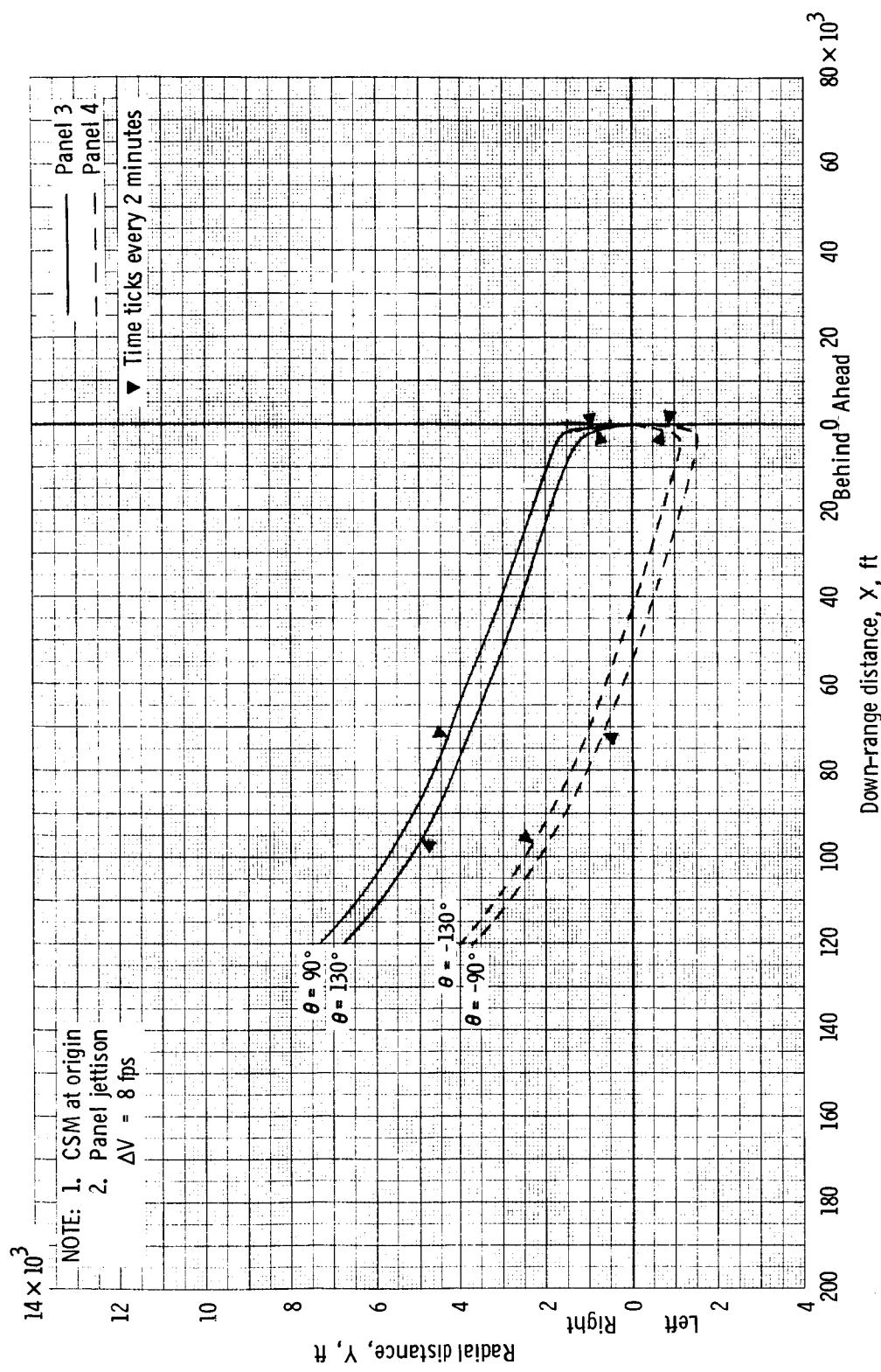
(b) Pitched panels for the middle of mode II.

Figure 2. - Continued.



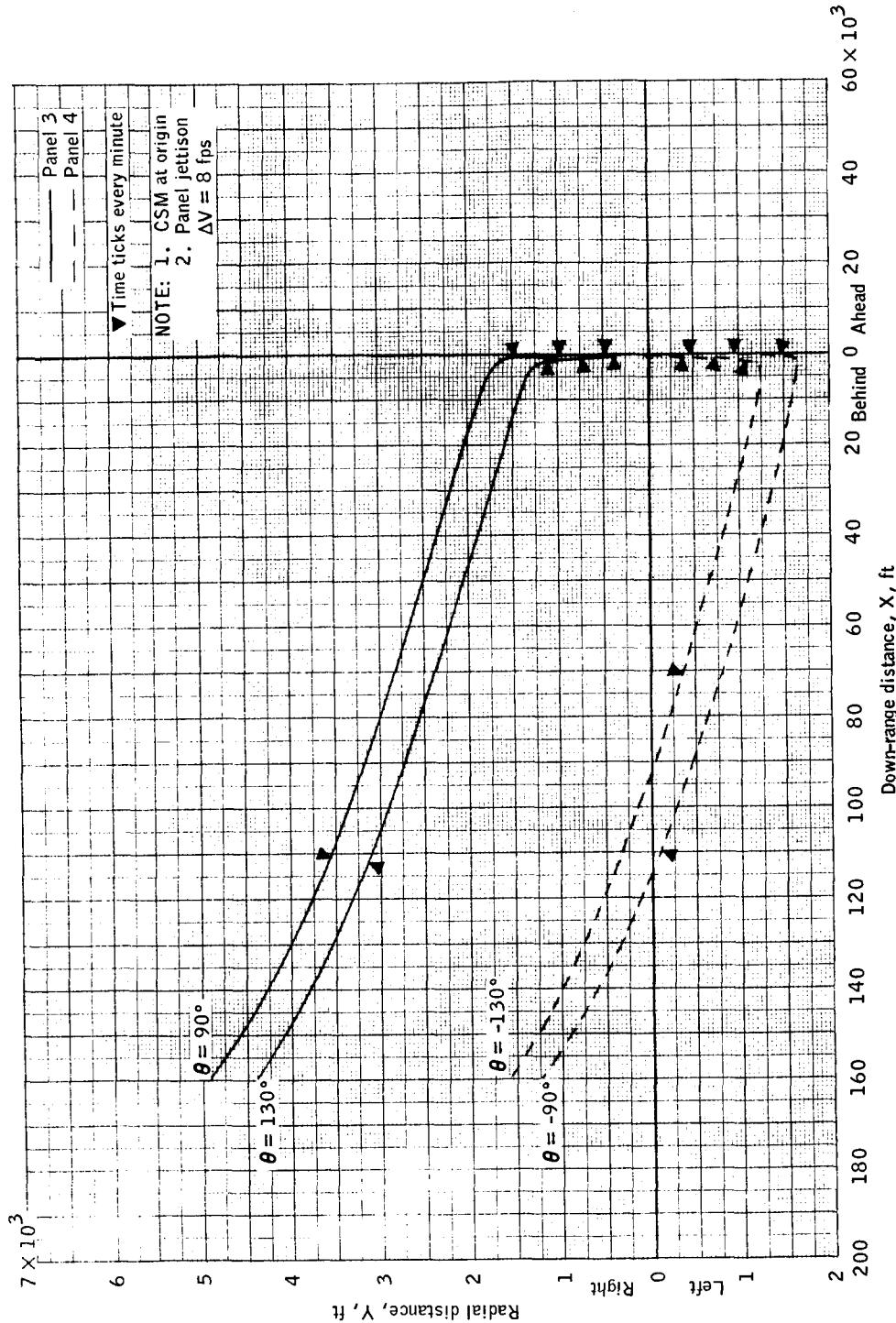
(c) Pitched panels for late mode II.

Figure 2. - Continued.



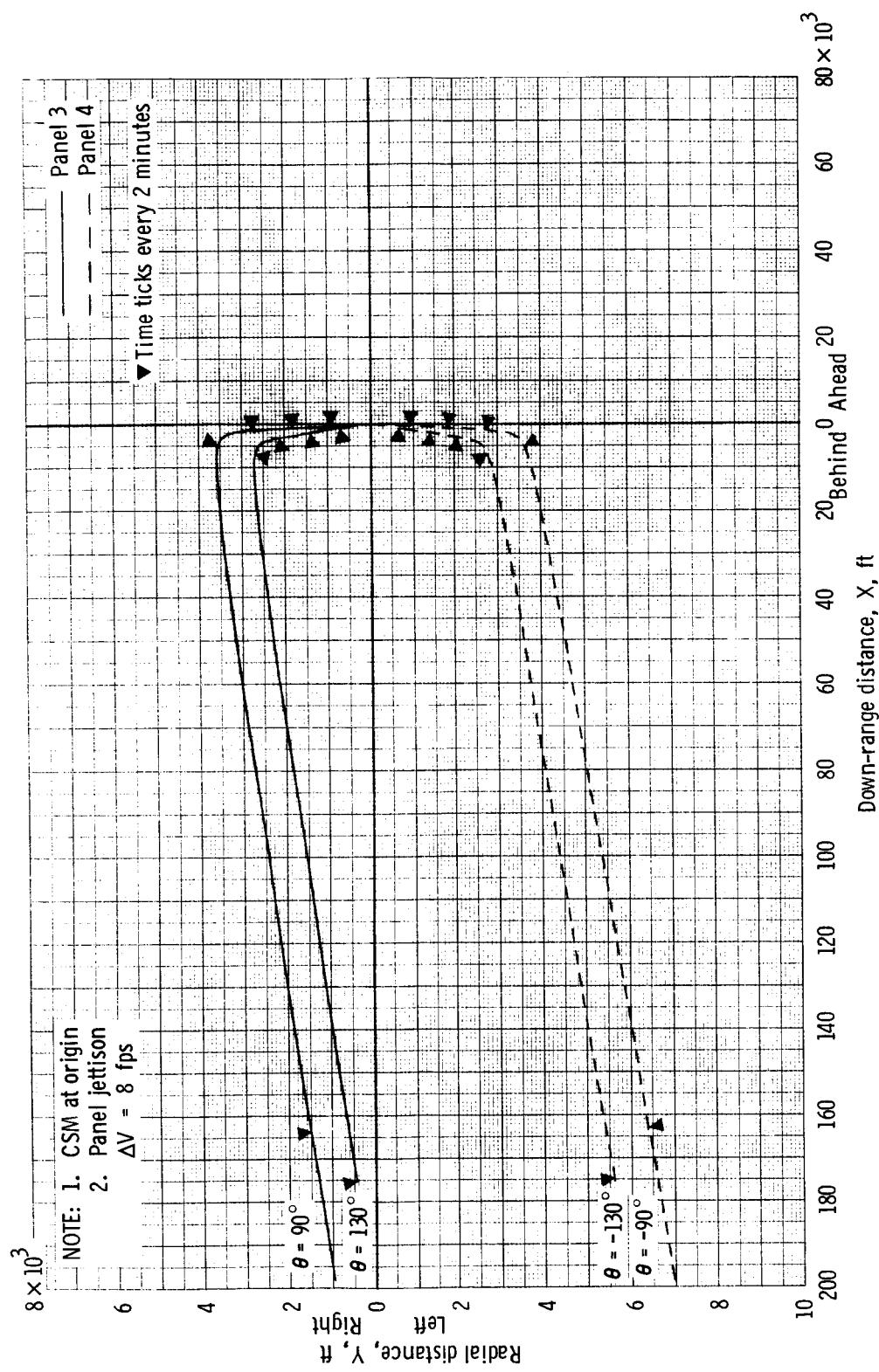
(d) Yawed panels for early mode III.

Figure 2.- Continued.



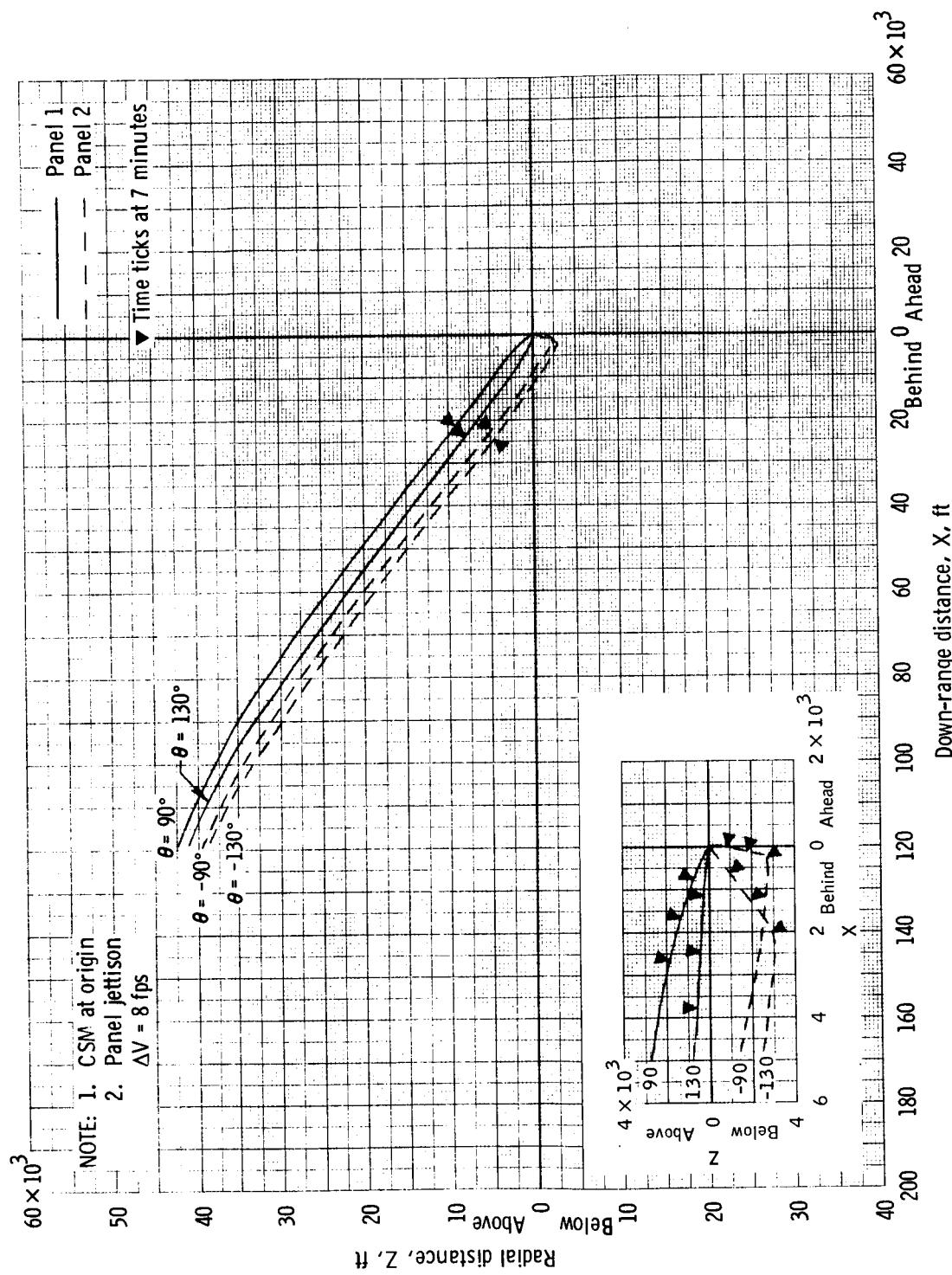
(e) Yawed panels for the middle of mode II.

Figure 2.-Continued.



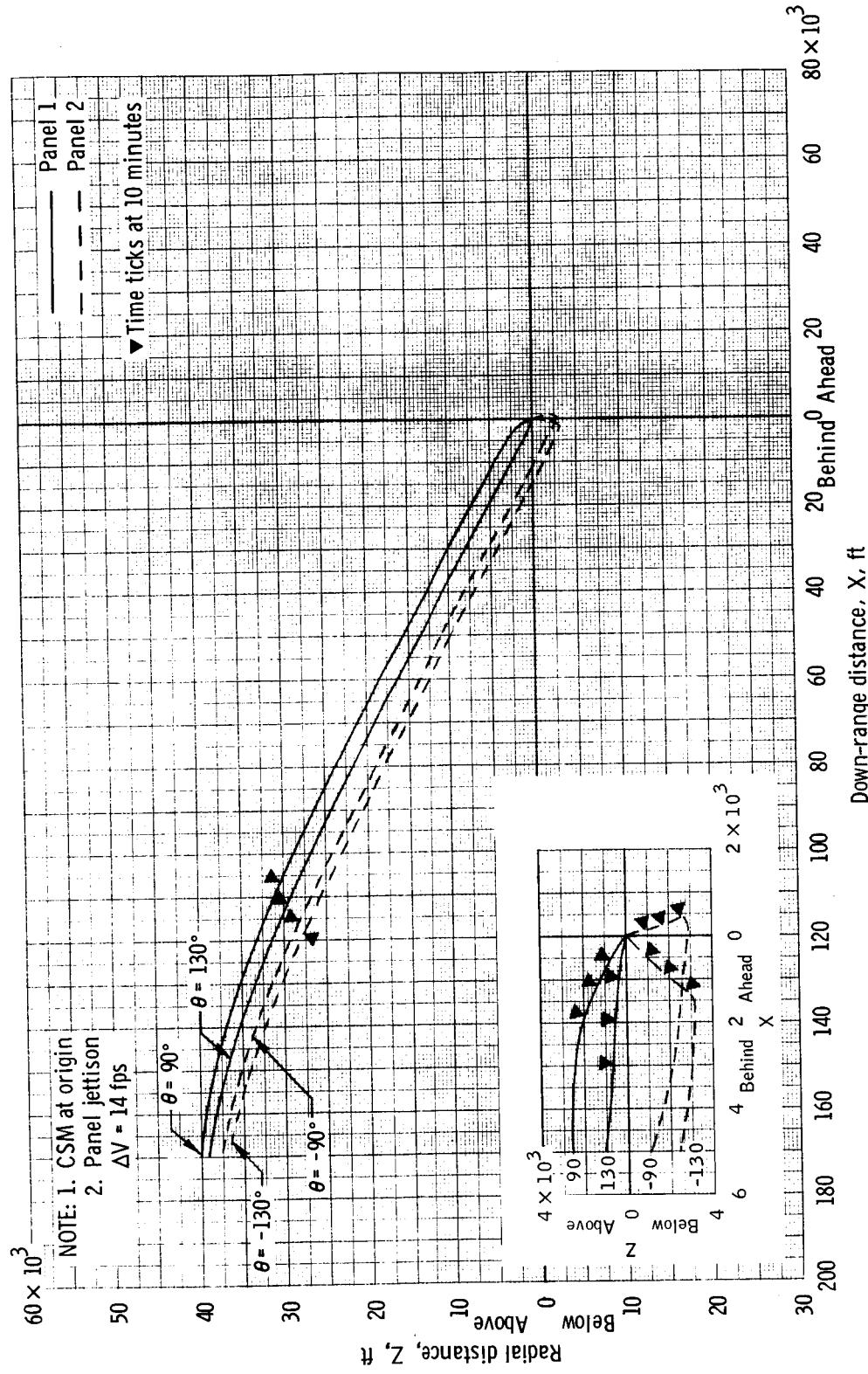
(f) Yawed panels for late mode II.

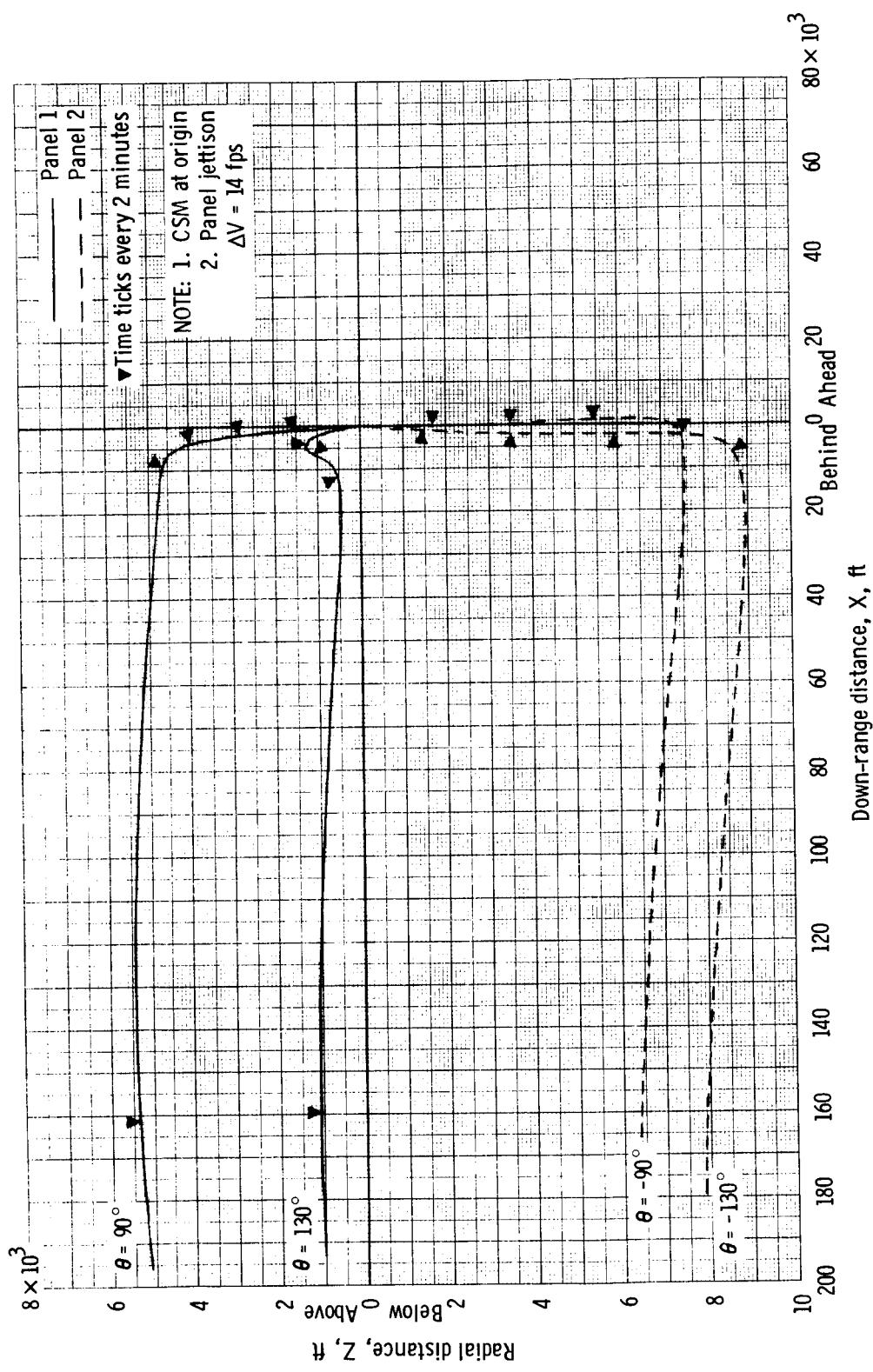
Figure 2.- Concluded.



(a) Pitched panels for early mode II.

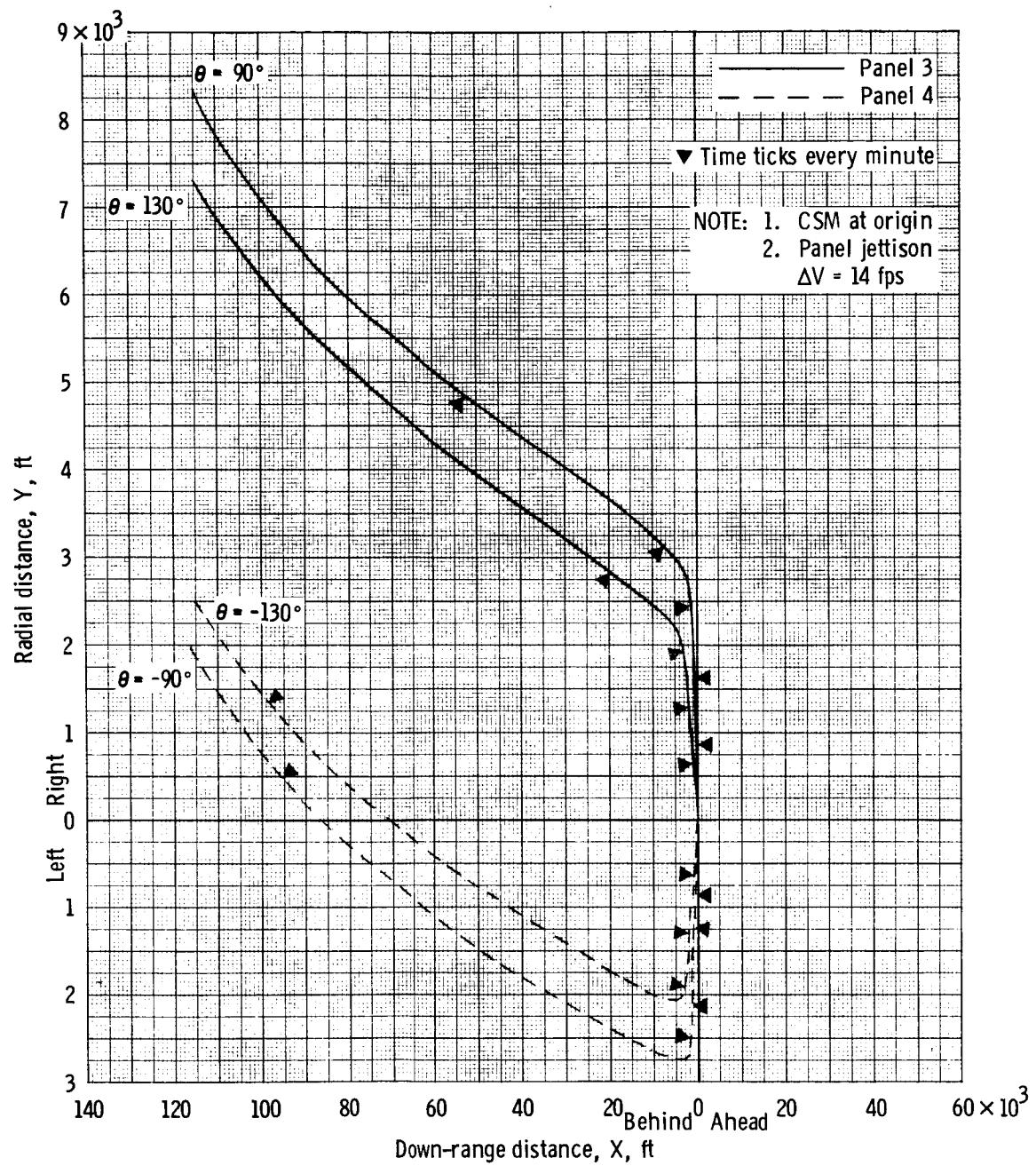
Figure 3. - SLA panels relative motion for mode II aborts, $\Delta V = 14 \text{ fps}$.





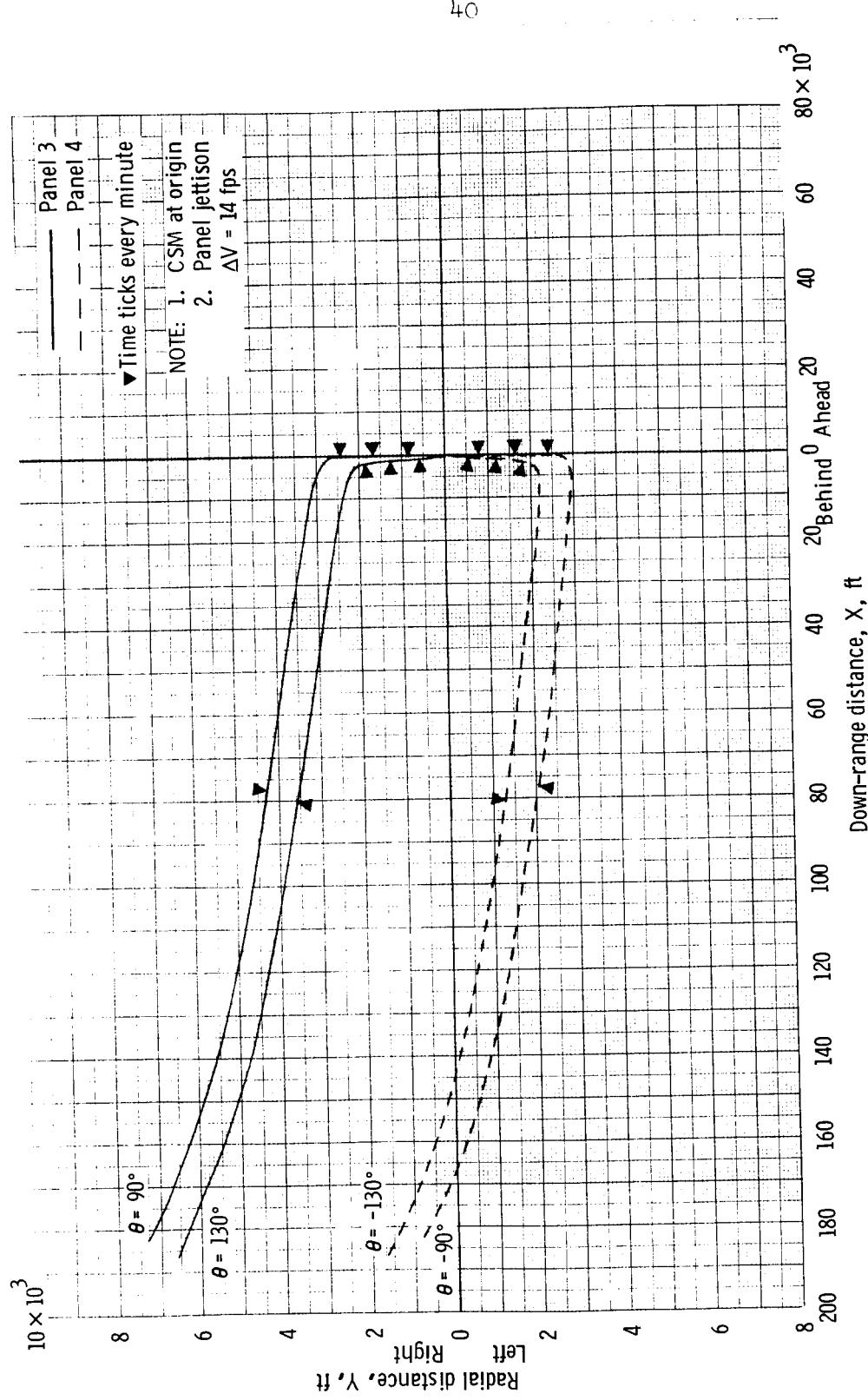
(c) Pitched panels for late mode II.

Figure 3. - Continued.



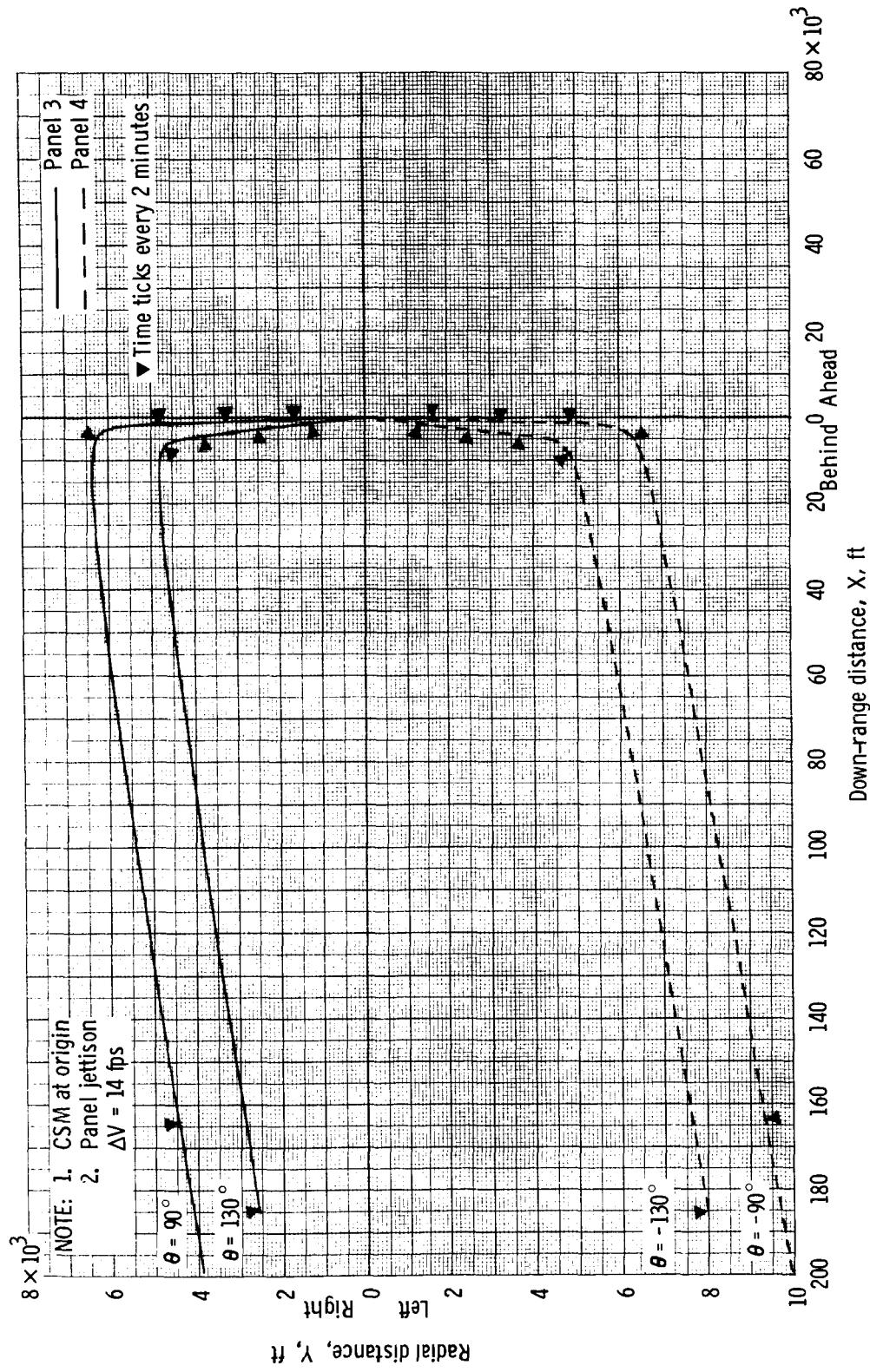
(d) Yawed panels for early mode II.

Figure 3. - Continued.



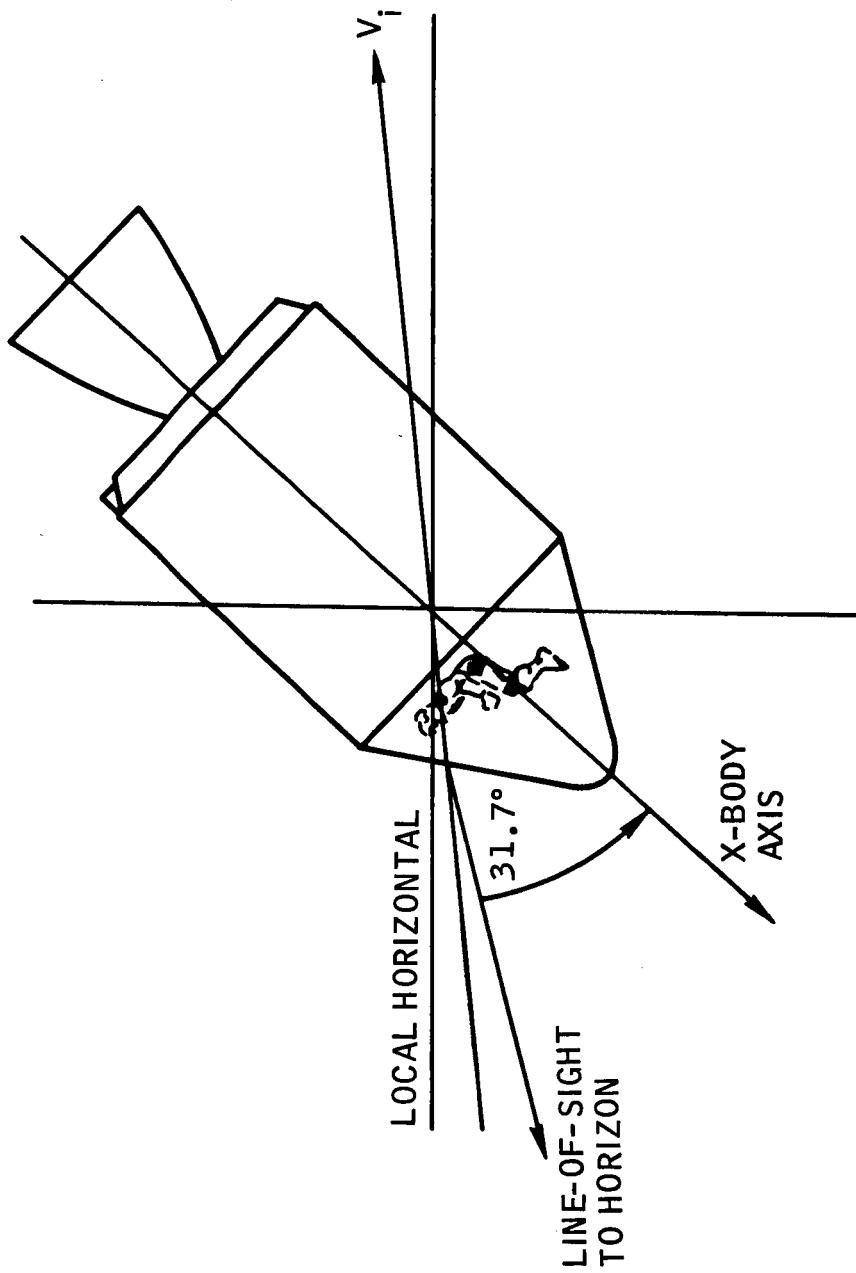
(e) Yawed panels for the middle of mode II.

Figure 3. - Continued.



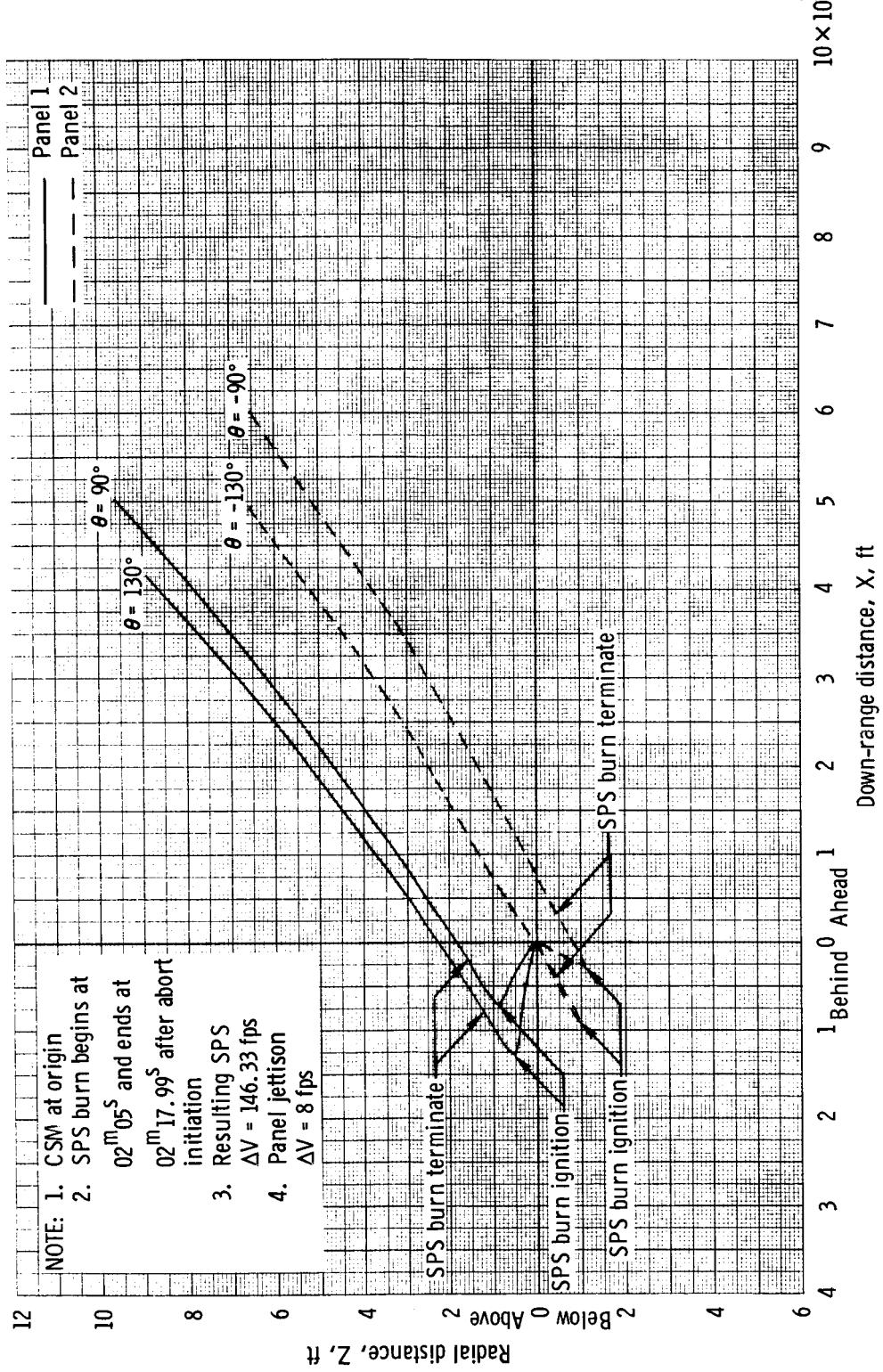
(f) Yawed panels for late mode II.

Figure 3.- Concluded.



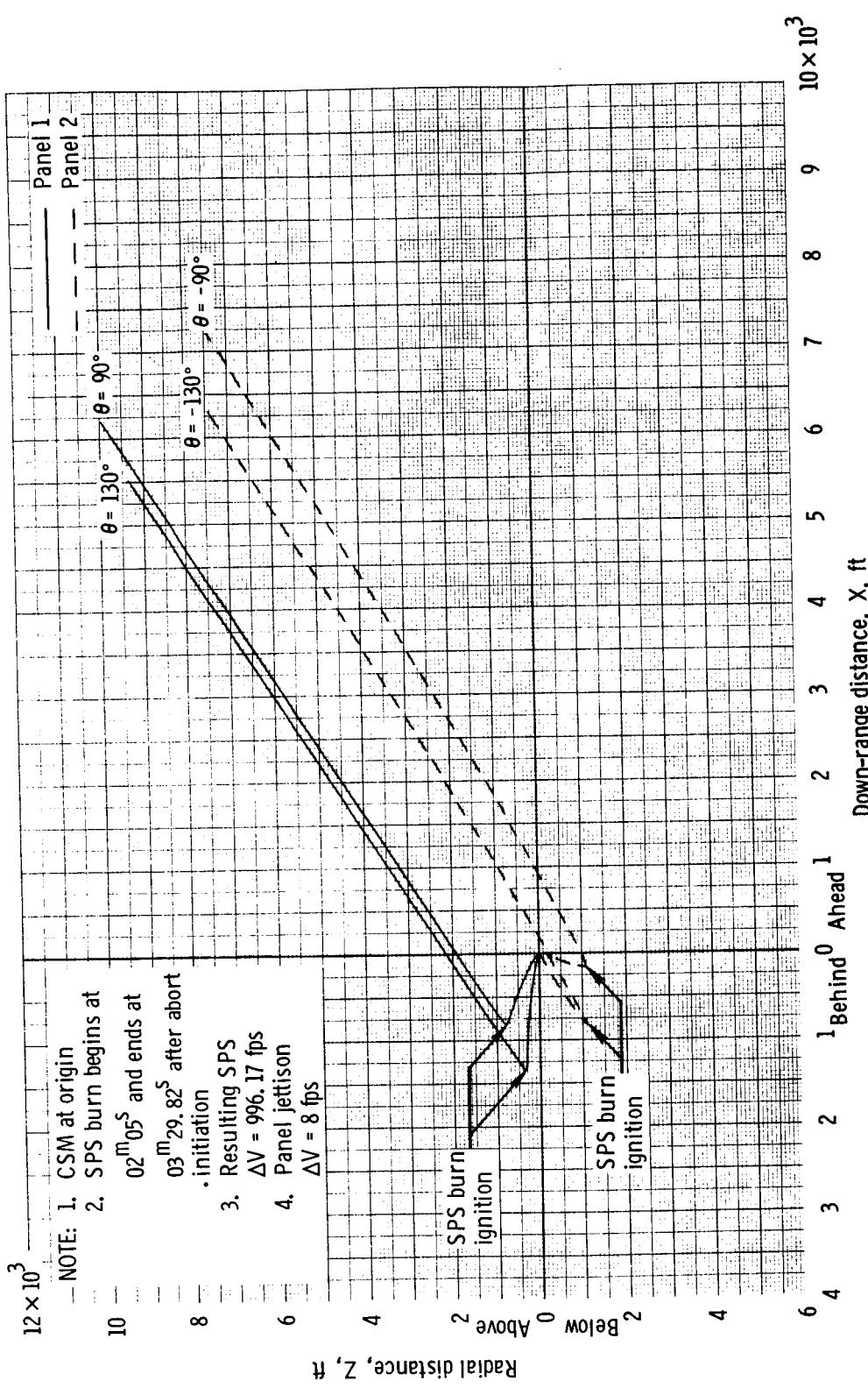
Note: The SCS holds this attitude inertially during
the deorbit burn

Figure 4.- CSM orientation attitude for a mode III abort, retrograde SPS deorbit burn, heads up.



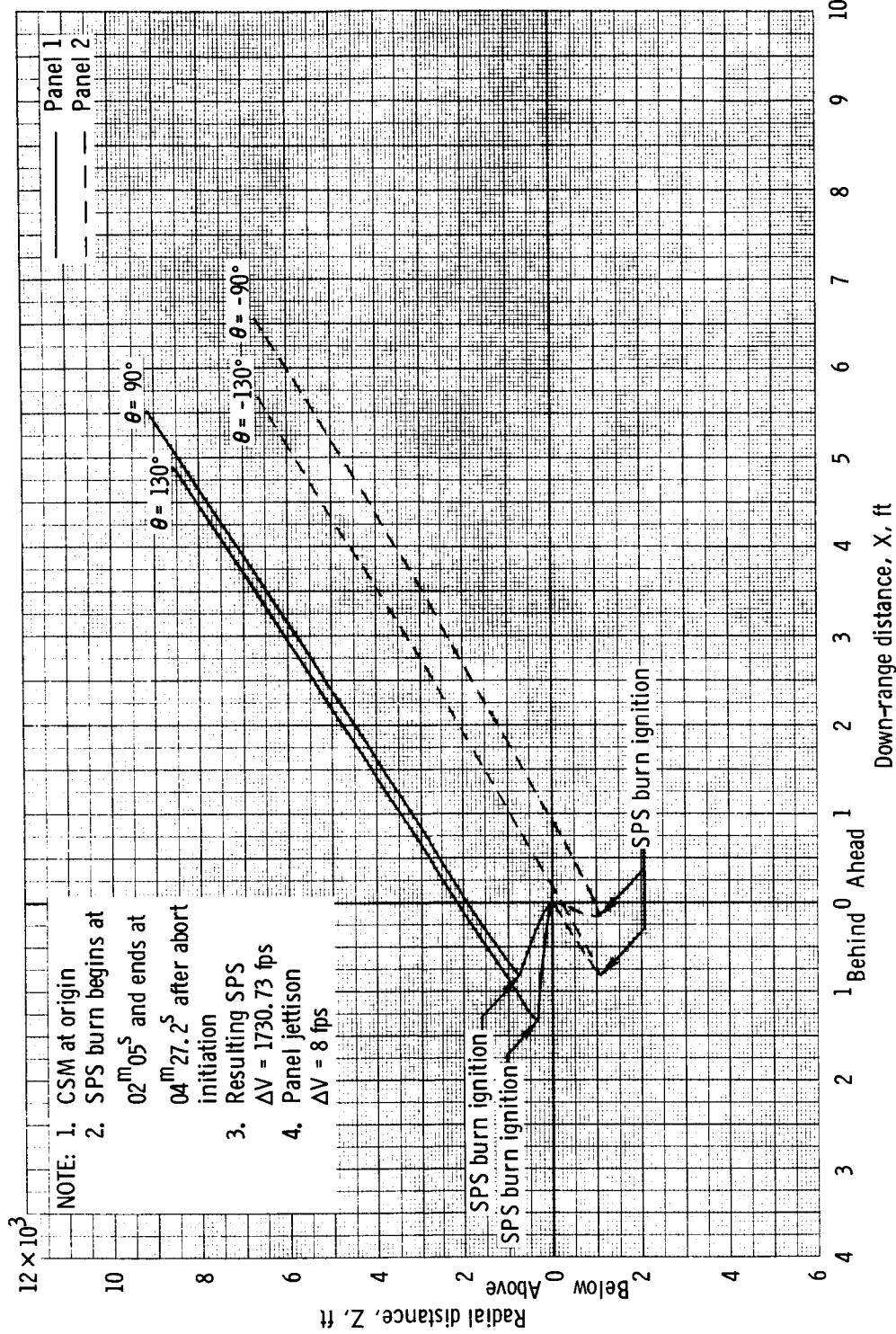
(a) Pitched panels for early mode IIII.

Figure 5. - SLA panels relative motion for mode IIII aborts, $\Delta V = 8$ fps.



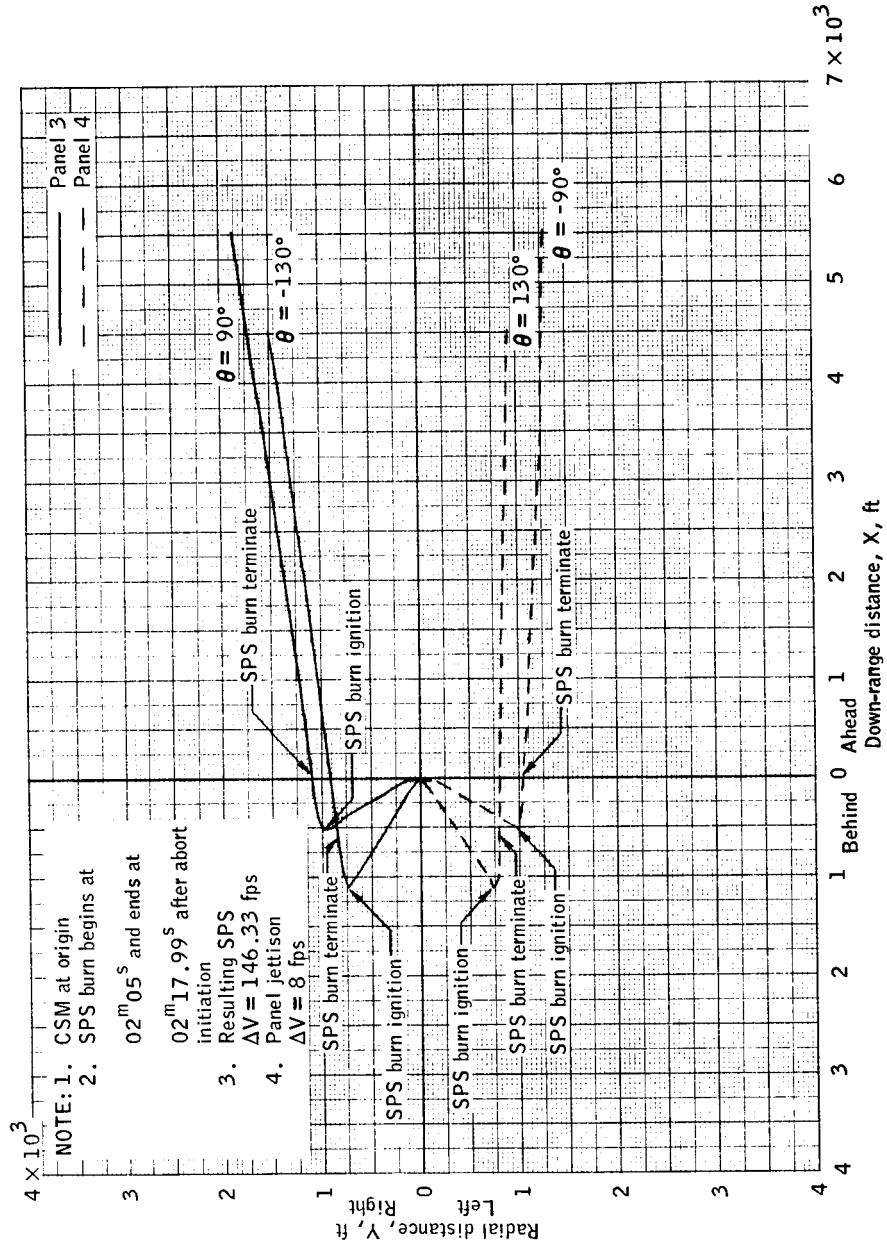
(b) Pitched panels for the middle of mode III.

Figure 5.- Continued.



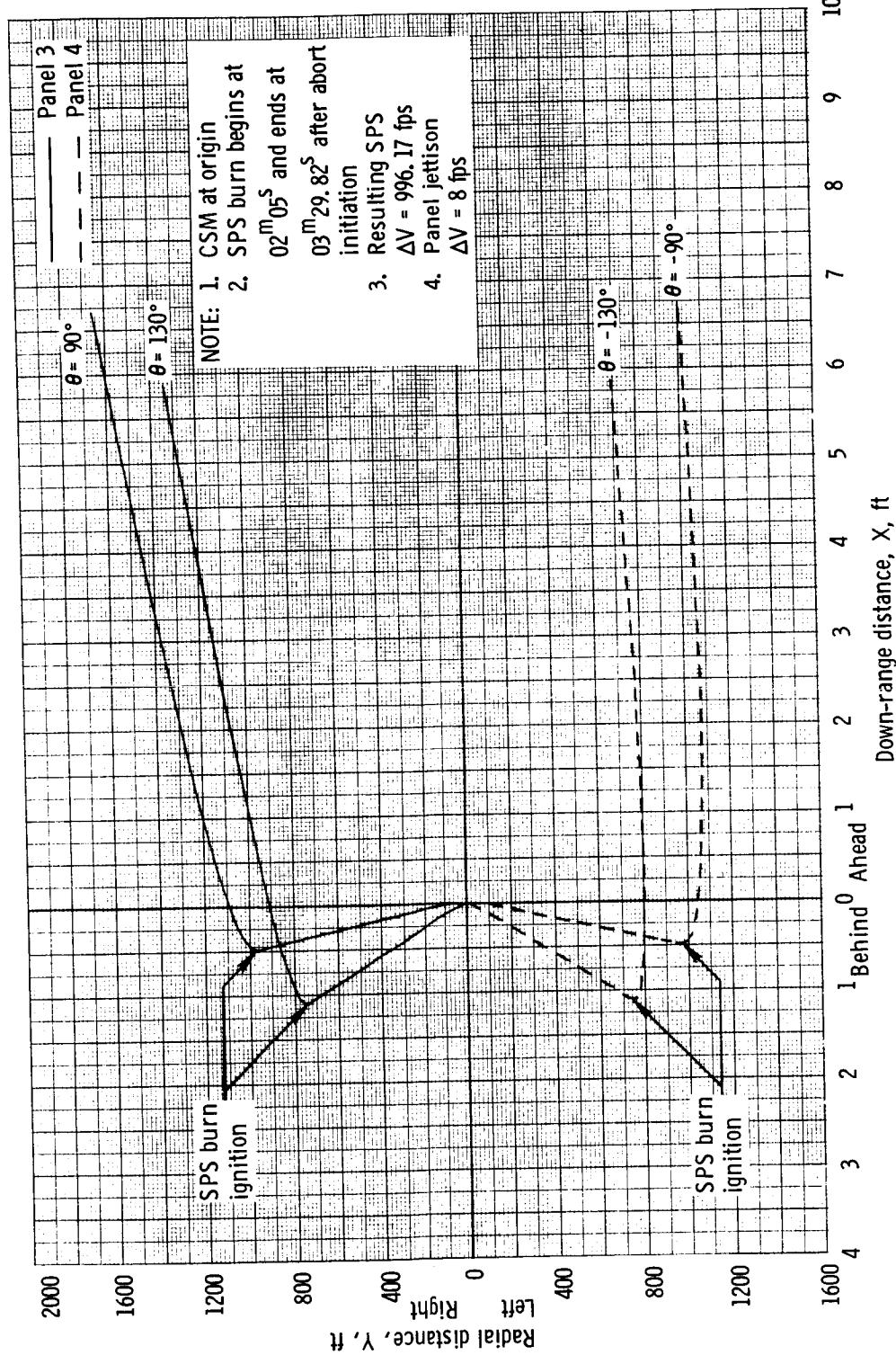
(c) Pitched panels for late mode III.

Figure 5 - Continued.



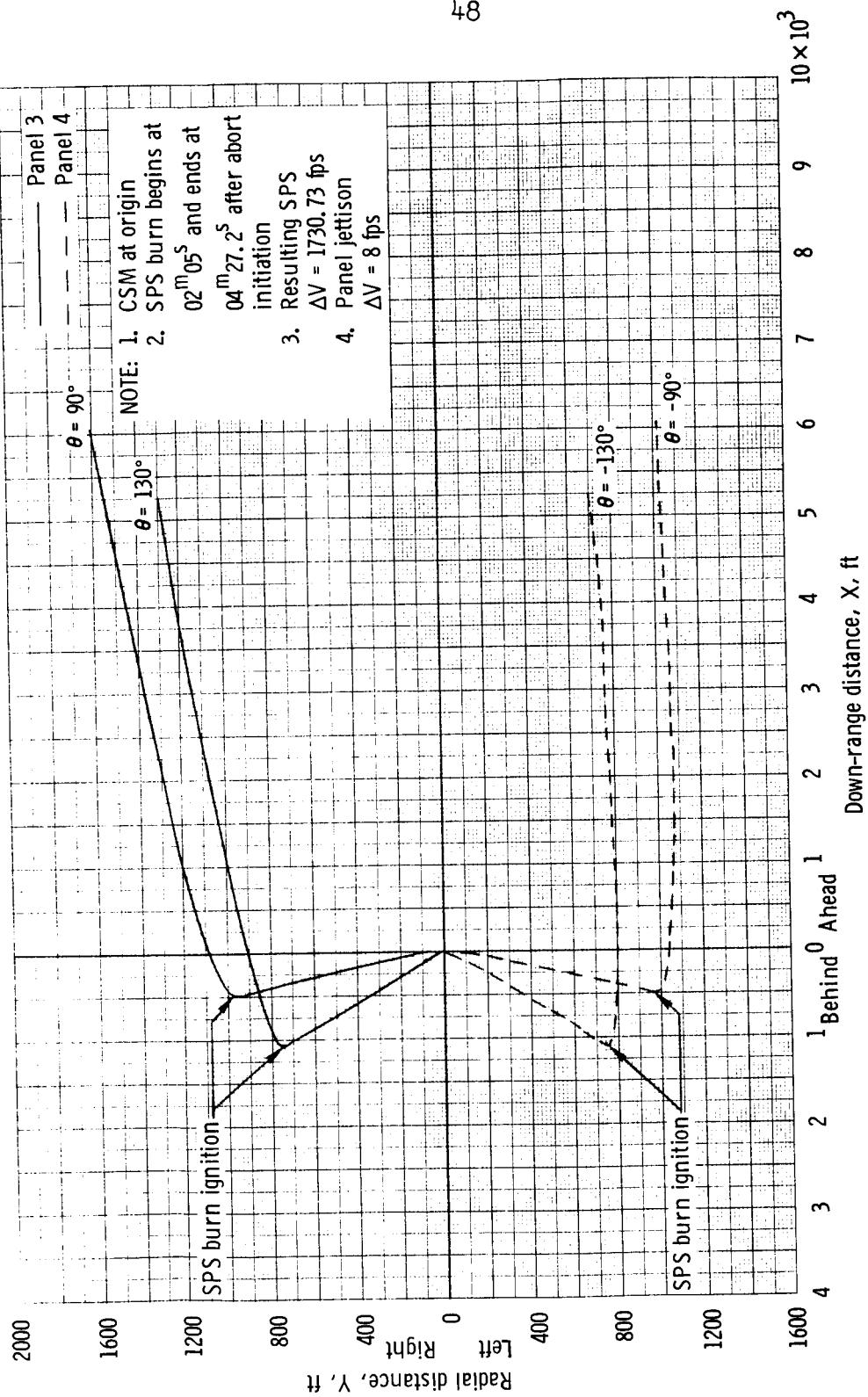
(d) Yawed panels for early mode III.

Figure 5.- Continued.



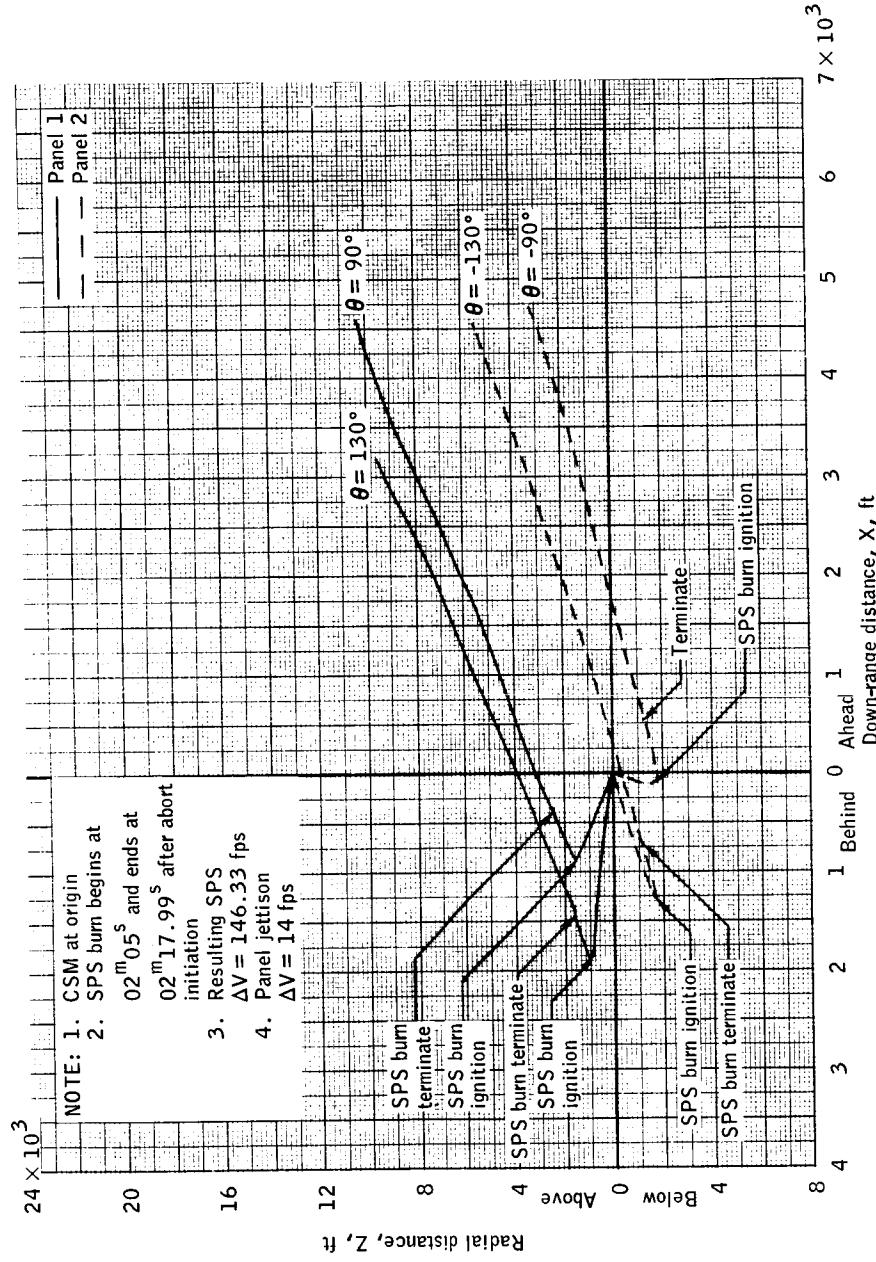
(e) Yawed panels for the middle of mode III.

Figure 5. - Continued.

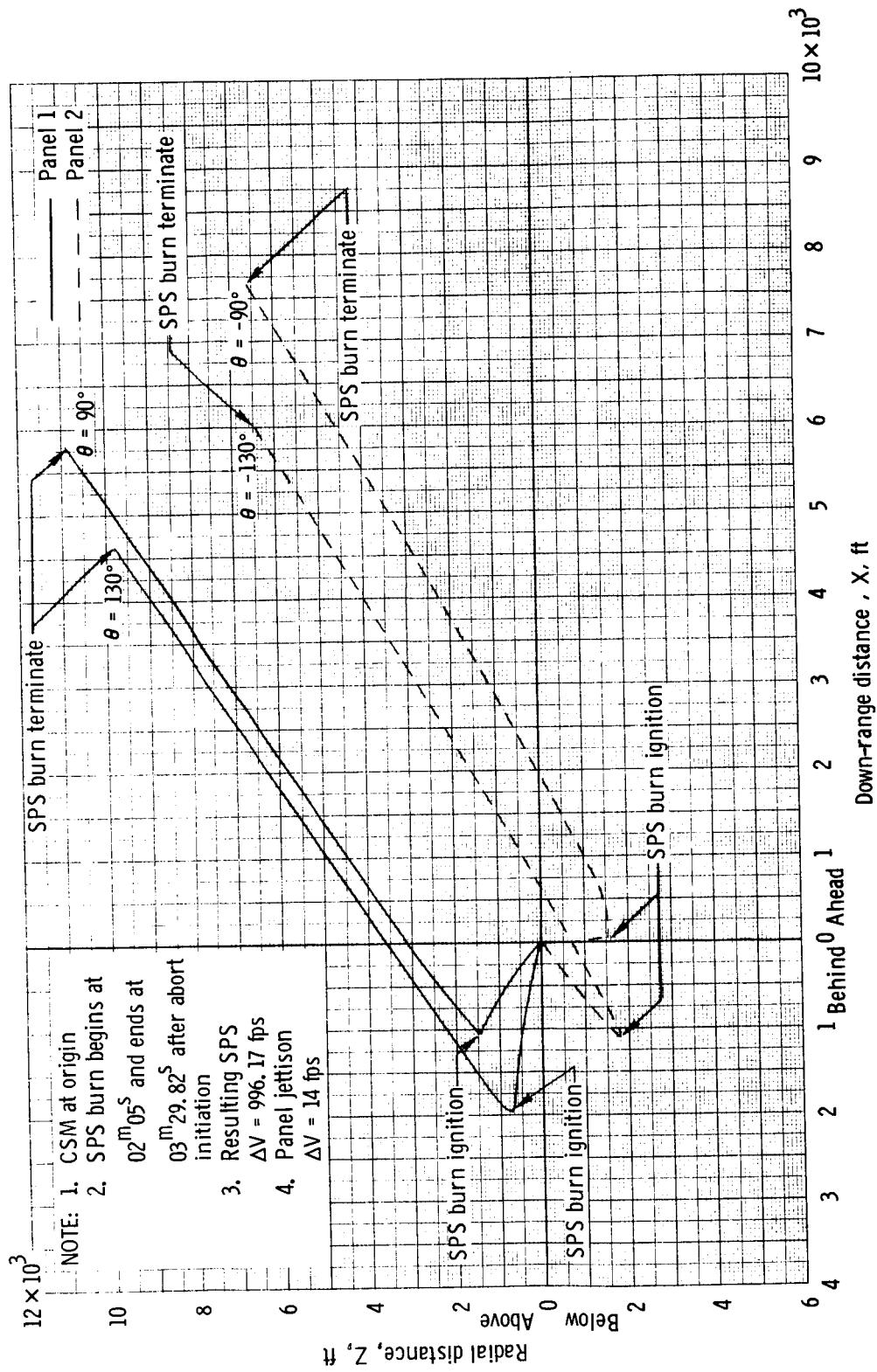


(f) Yawed panels for late mode III.

Figure 5.- Continued.

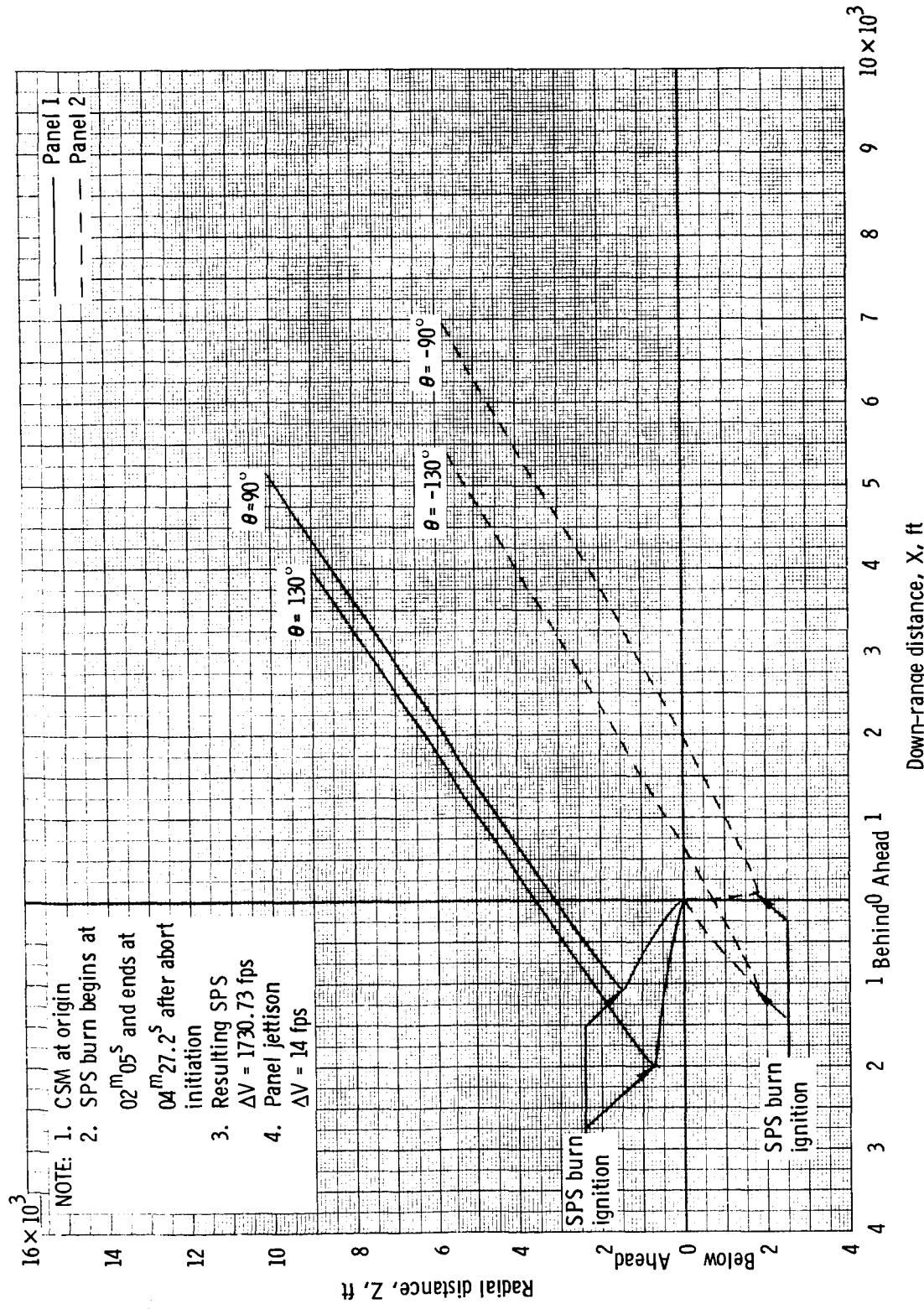


(a) Pitched panels for early mode III.
Figure 6.- SLA panels relative motion for mode III aborts, $\Delta V = 14$ fps.



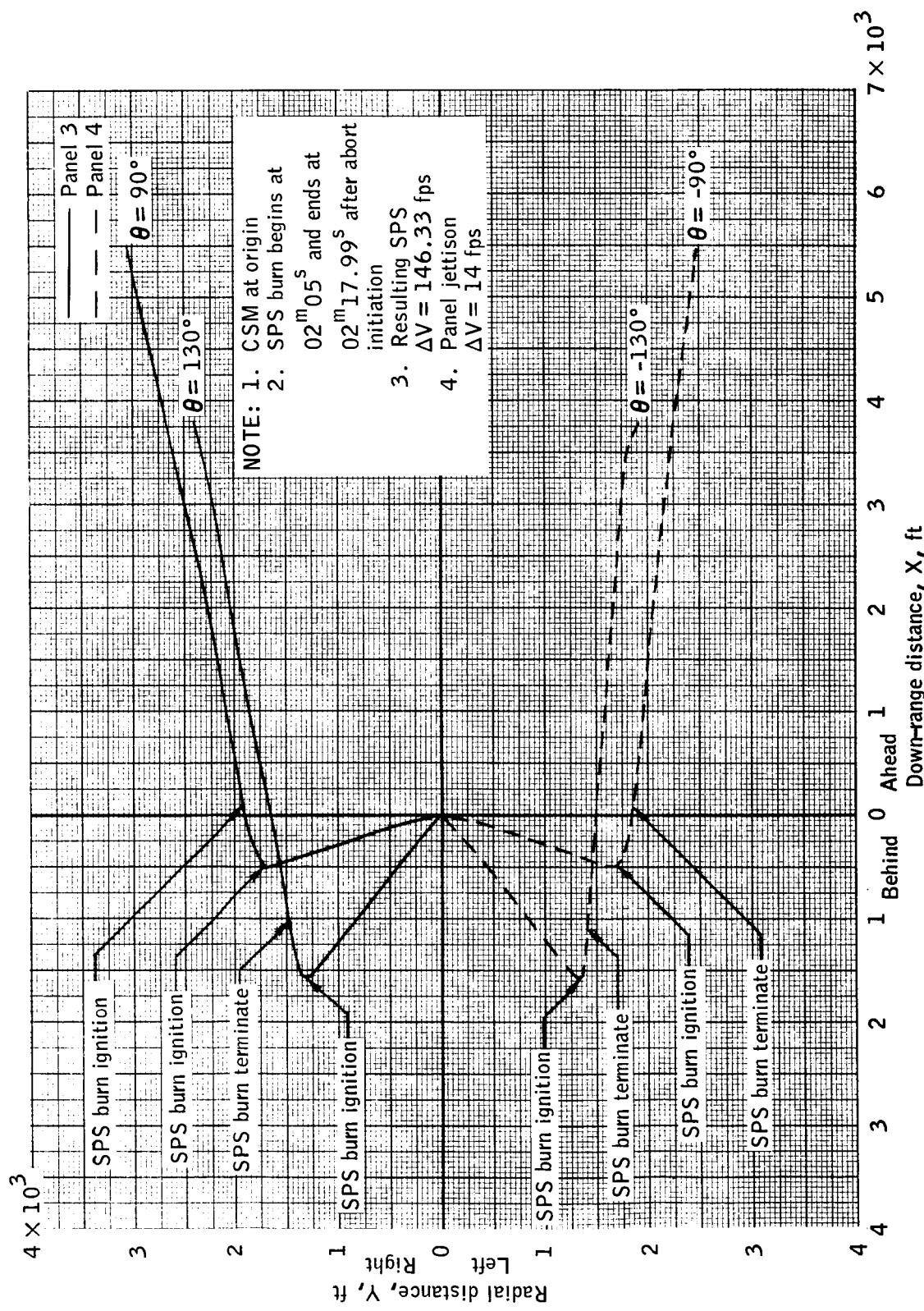
(b) Pitched panels for the middle of mode III.

Figure 6 - Continued.



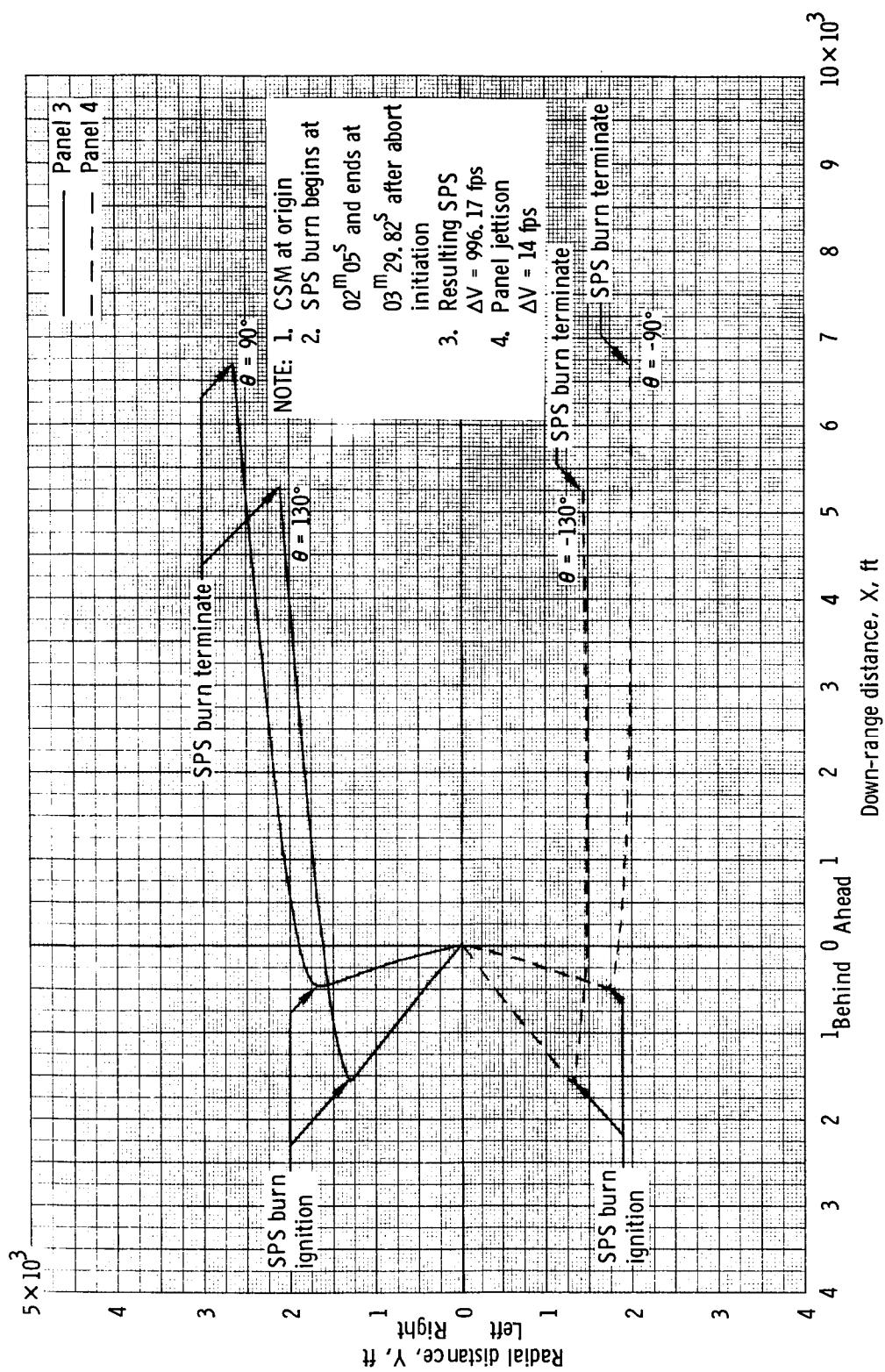
(c) Pitched panels for late mode III.

Figure 6. - Continued.



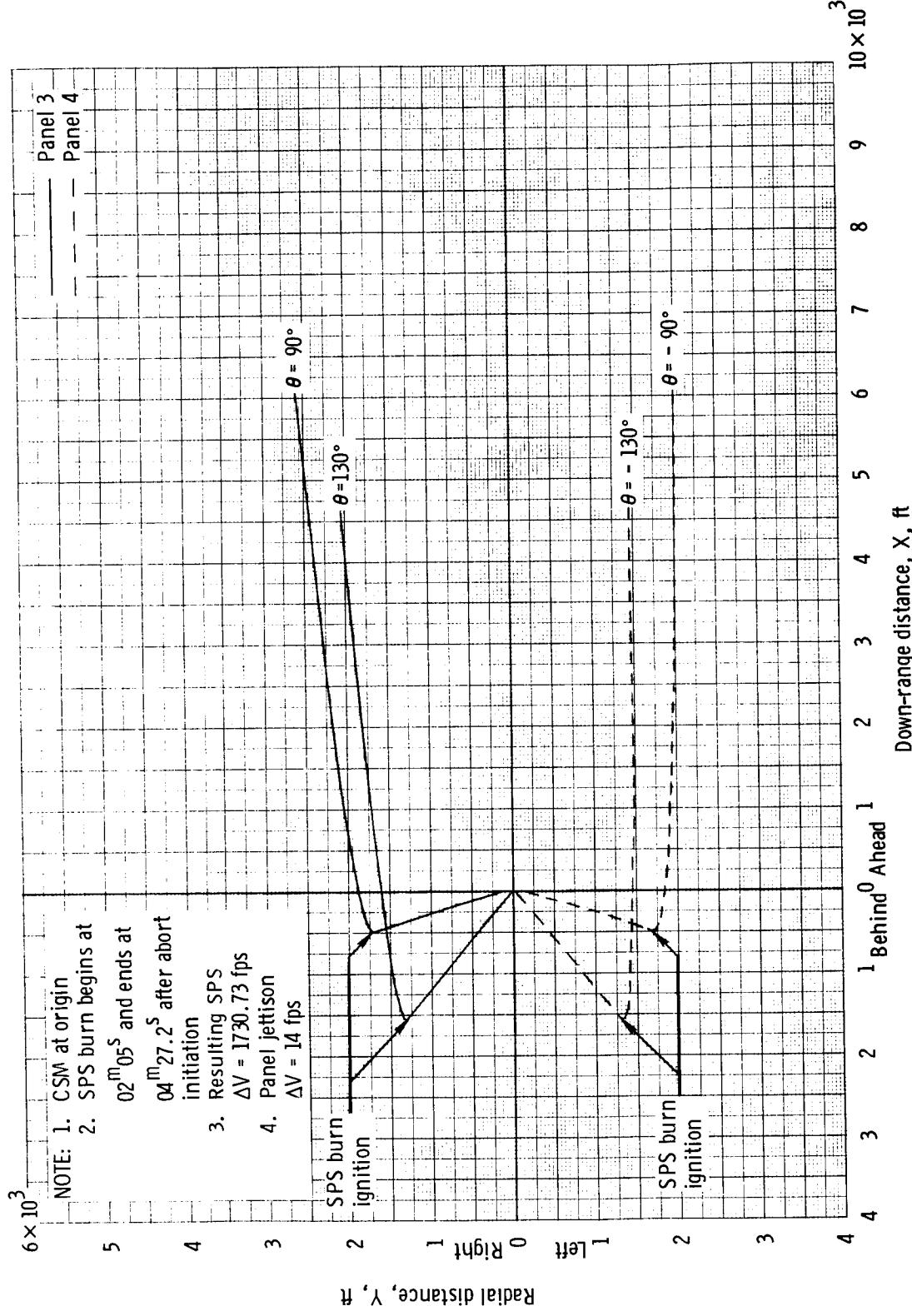
(d) Yawed panels for early mode III.

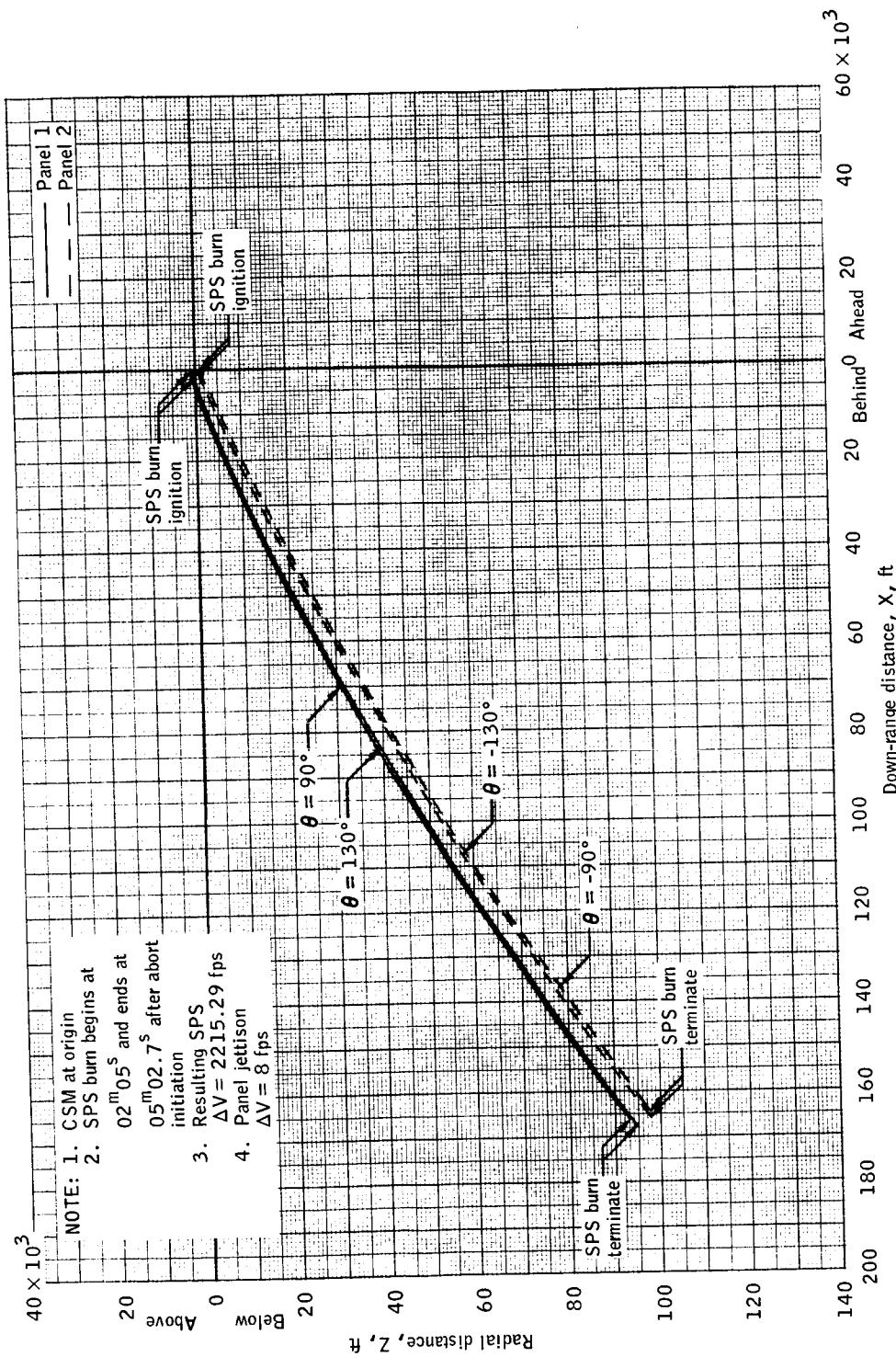
Figure 6.- Continued.



(e) Yawed panels for the middle of mode III.

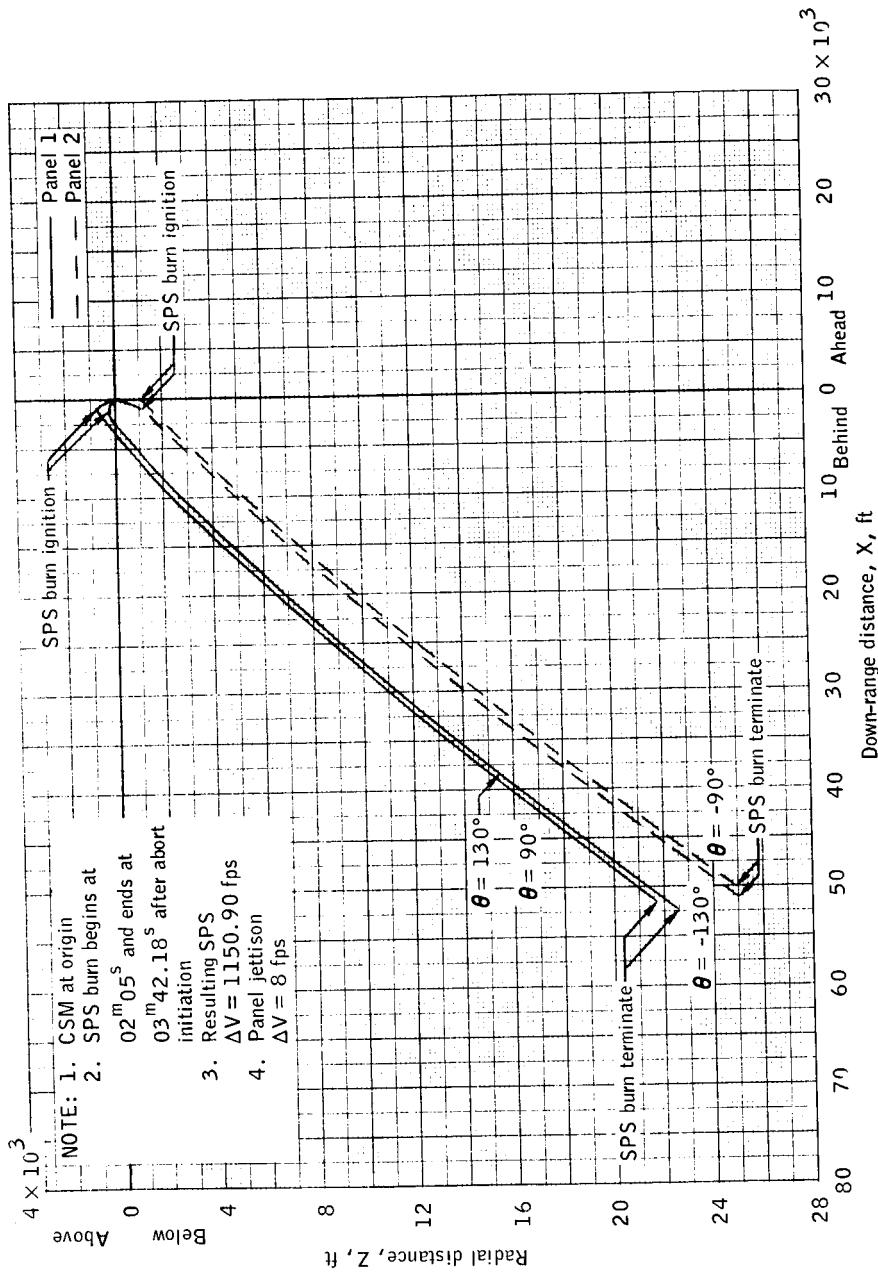
Figure 6.- Continued.





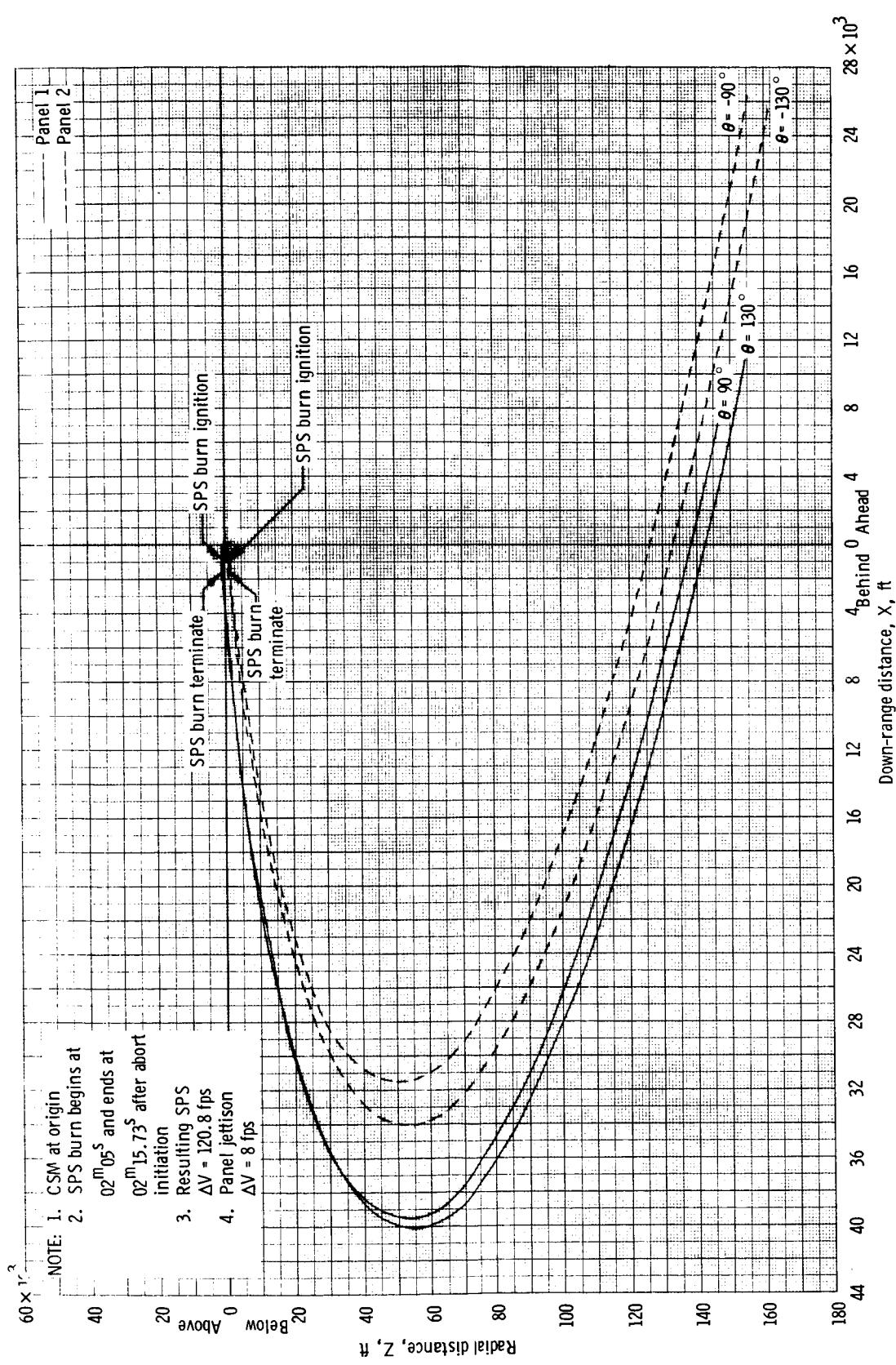
(a) Pitched panels for early mode IV.

Figure 7. - SLA panels relative motion for mode IV aborts, $\Delta V = 8$ fps.



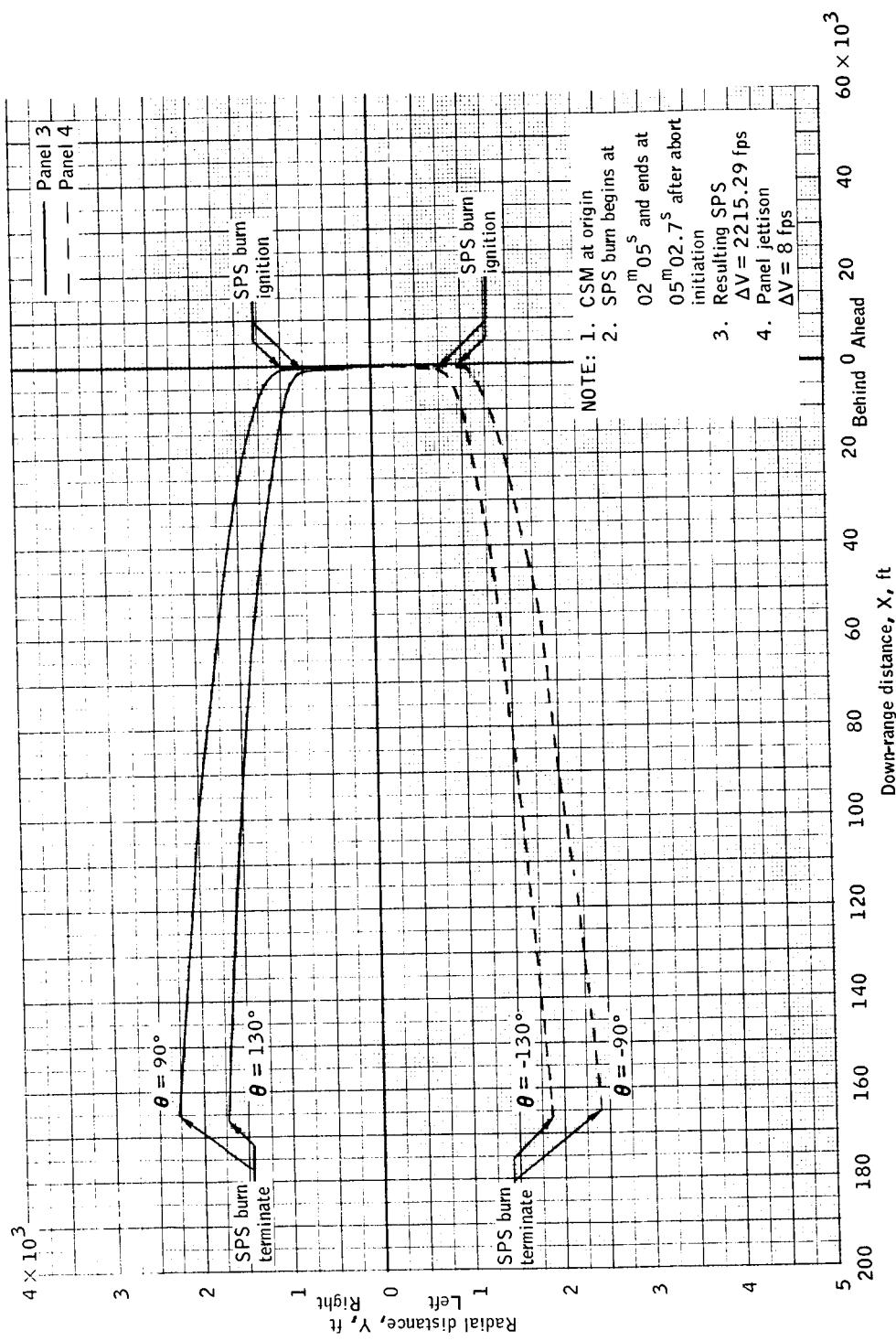
(b) Pitched panels for the middle of mode IV.

Figure 7. - Continued.



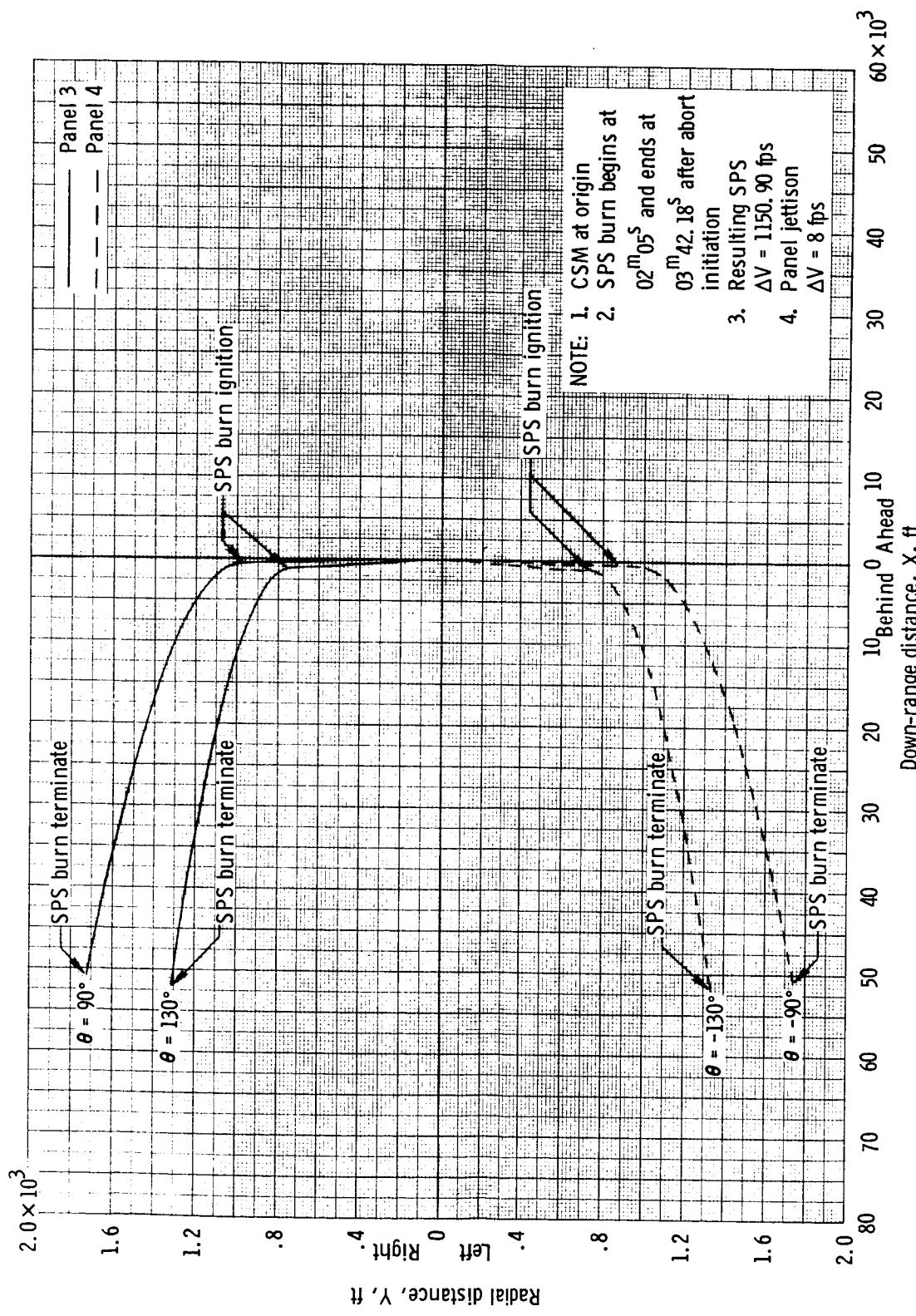
(c) Pitched panels for late mode IV.

Figure 7. - Continued.



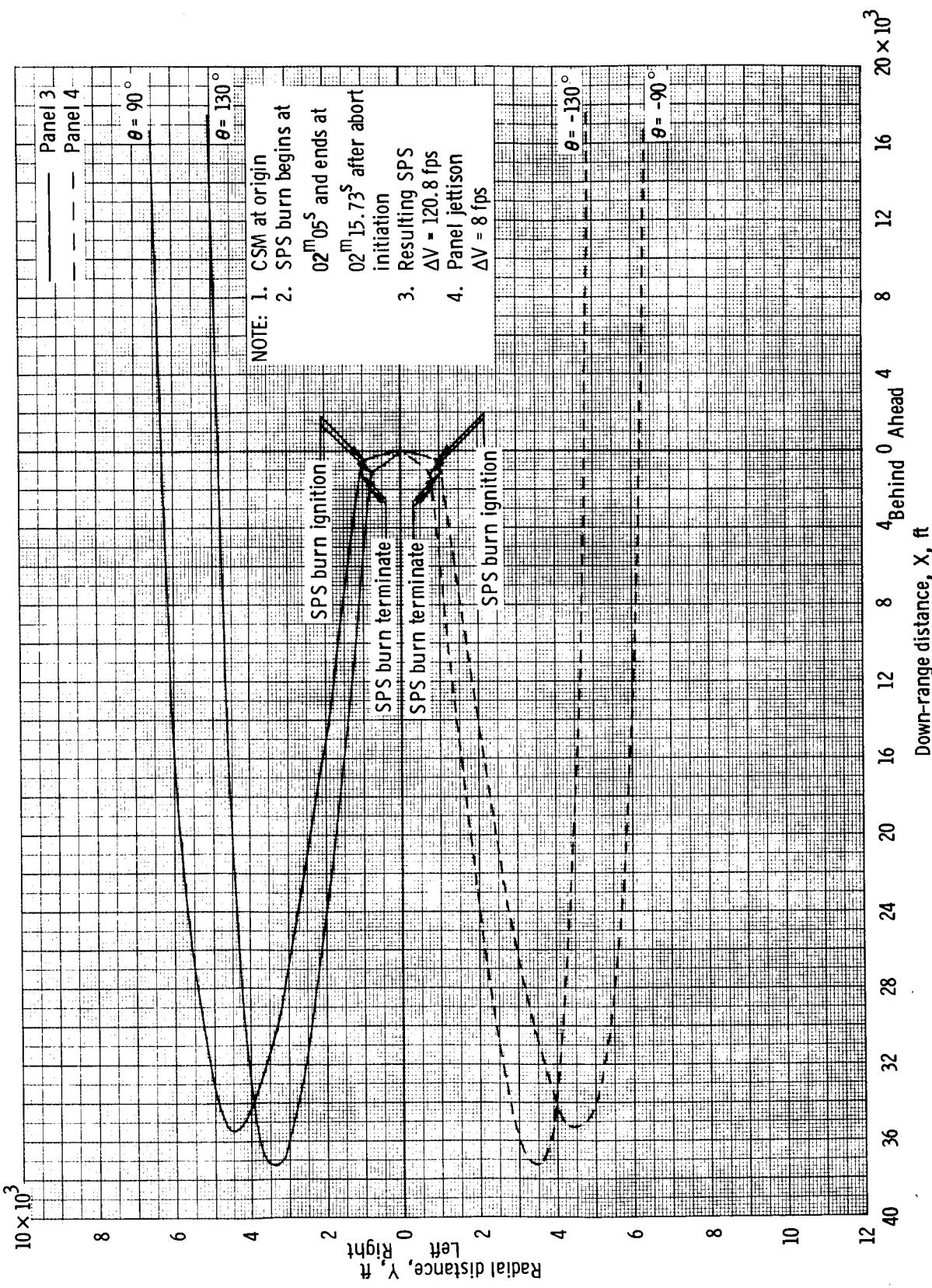
(d) Yawed panels for early mode IV.

Figure 7. - Concluded.



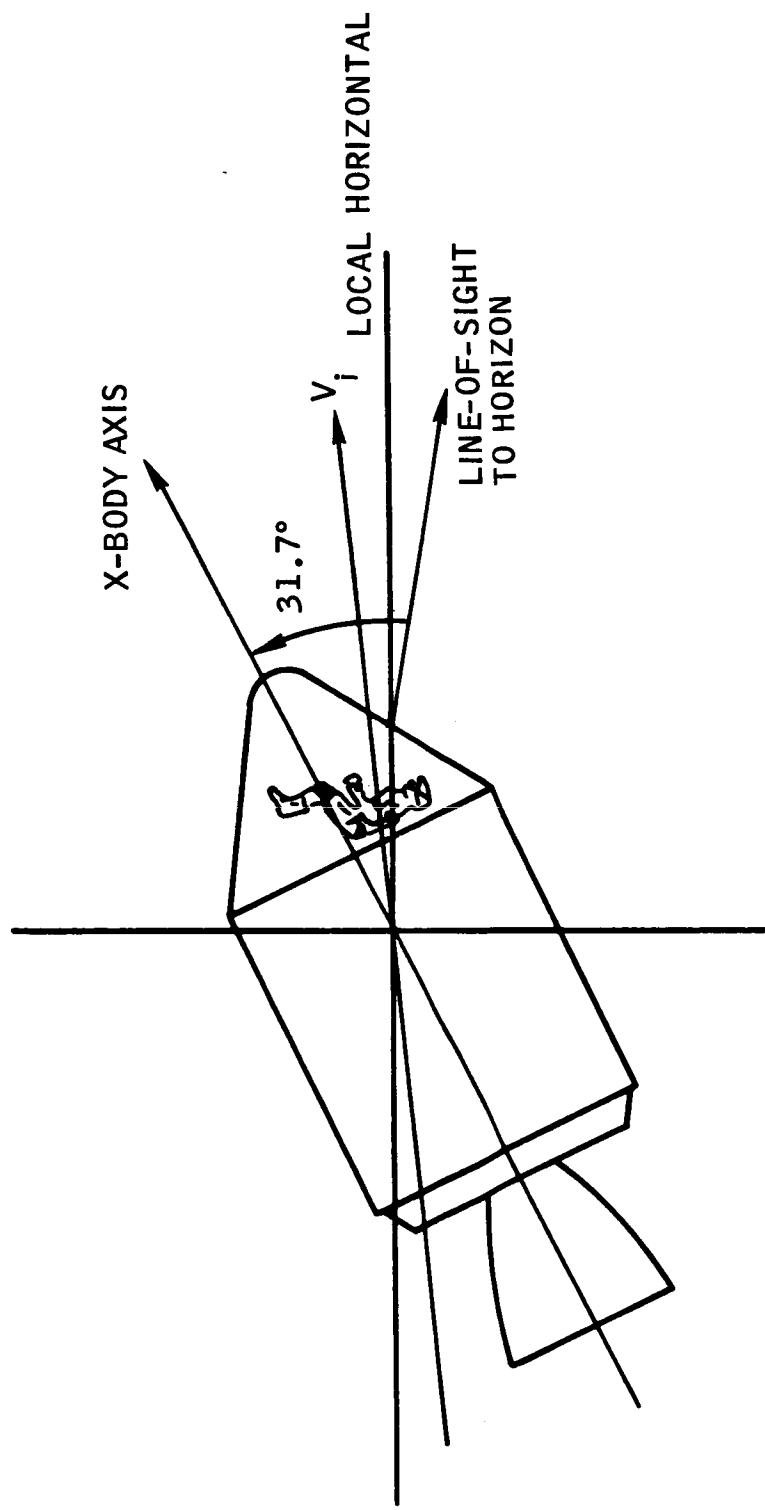
(e) Yawed panels for the middle of mode IV.

Figure 7. - Continued.



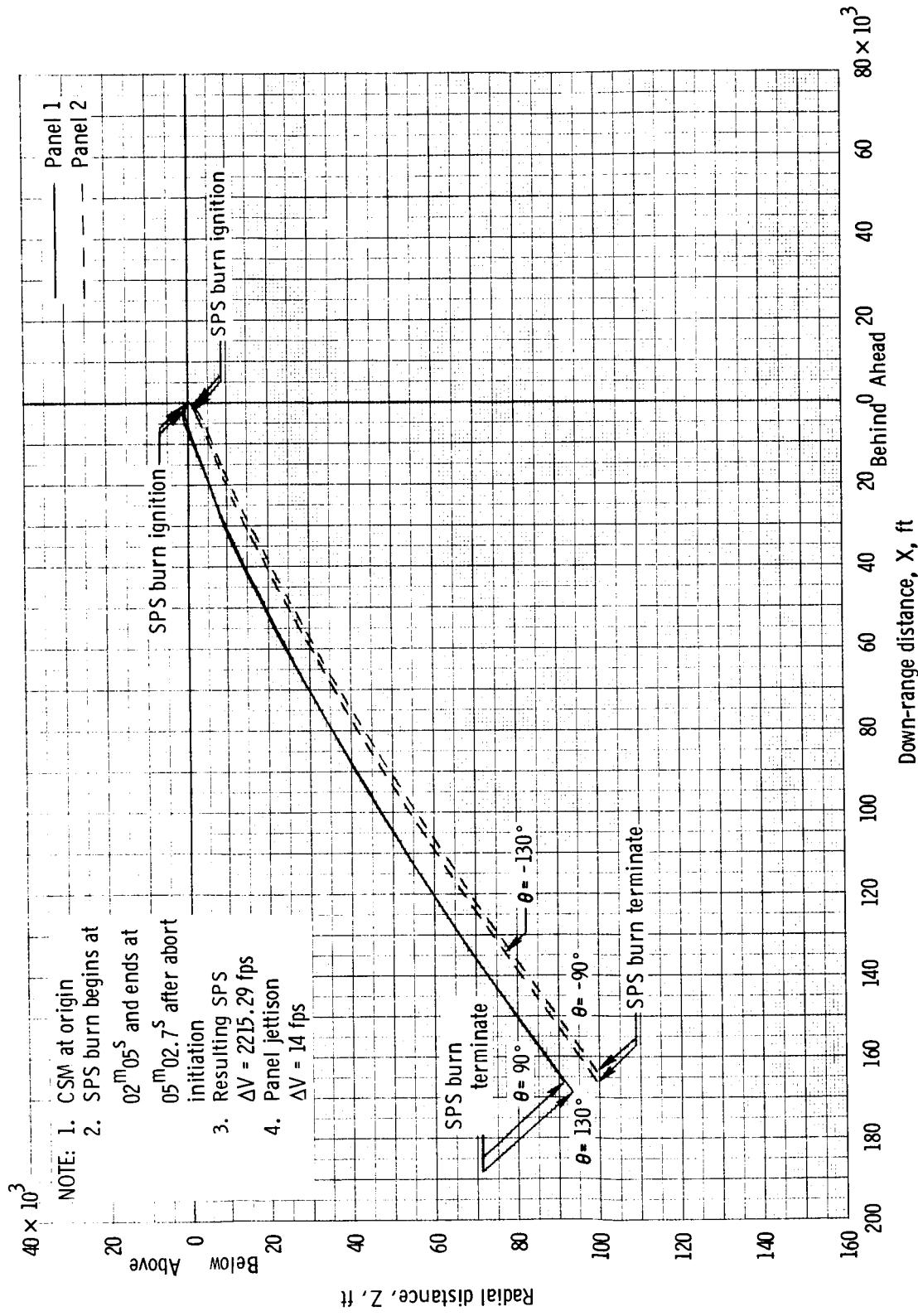
(f) Yawed panels for late mode IV.

Figure 7.- Concluded.

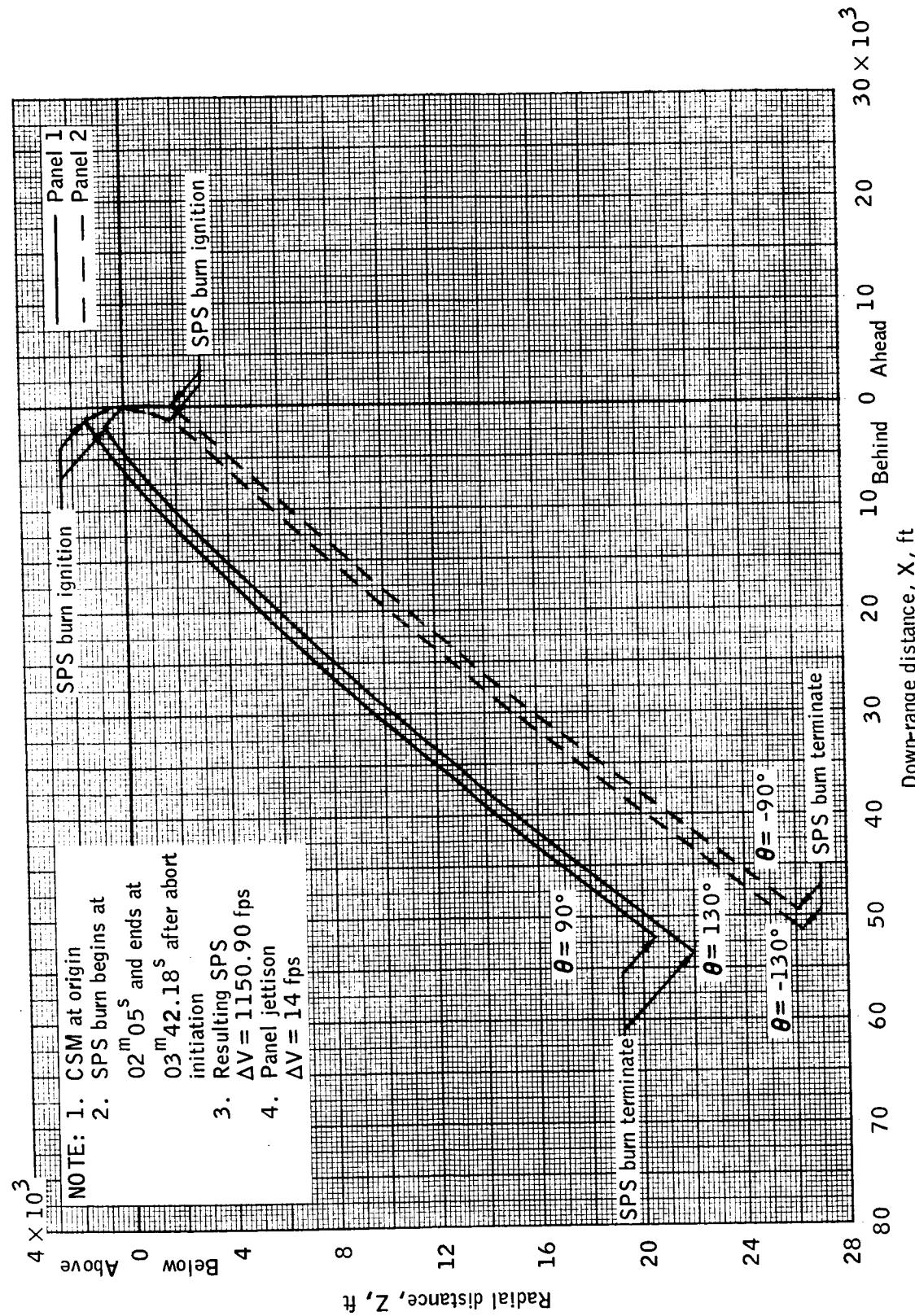


Note: The SCS holds this attitude inertially during
the COI burn

Figure 8.- CSM orientation attitude for a mode IV abort, posigrade COI burn, heads down.

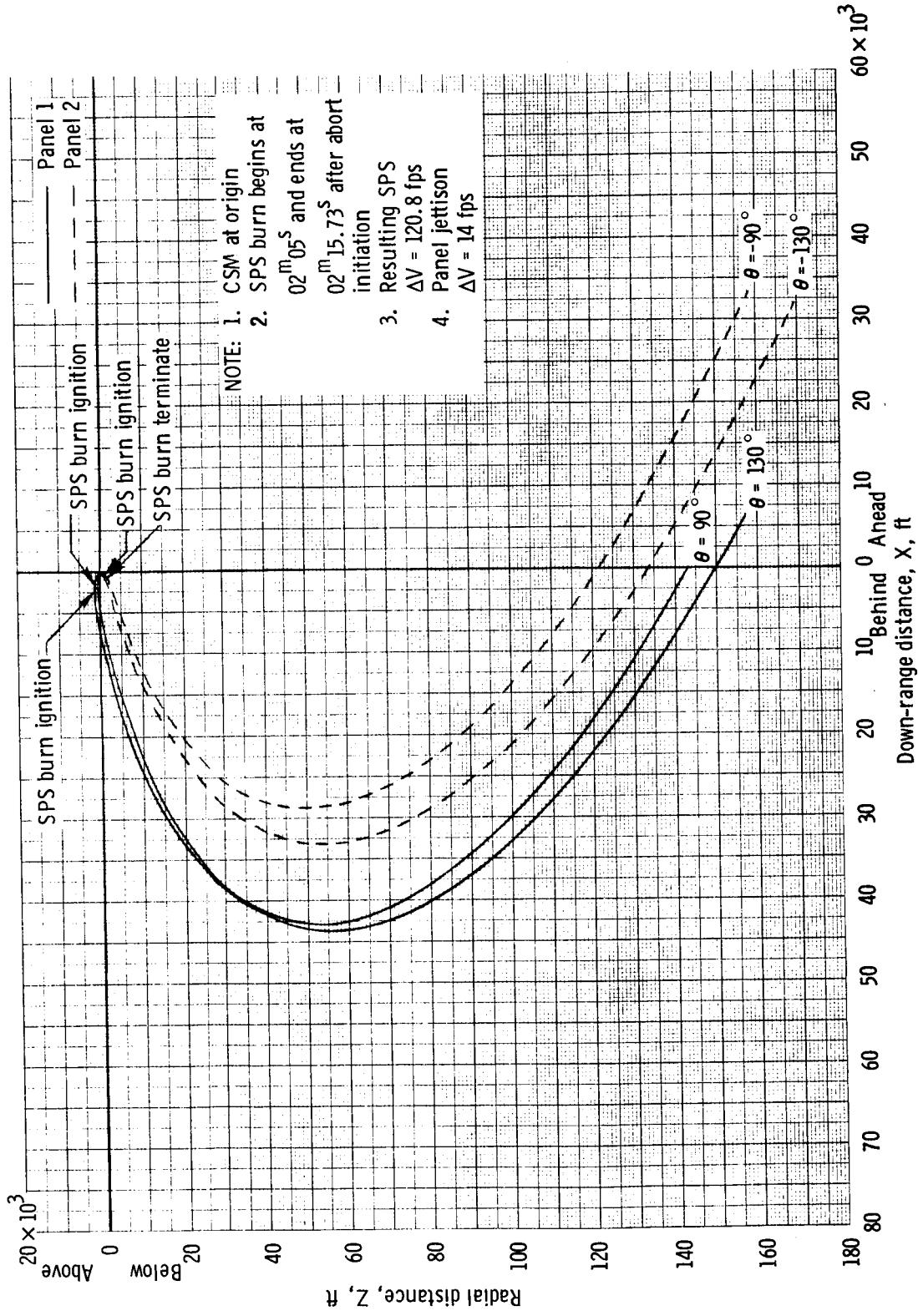


(a) Pitched panels for early mode IV.
Figure 9. - SLA panel relative motion for mode IV aborts, $\Delta V = 14$ fps.



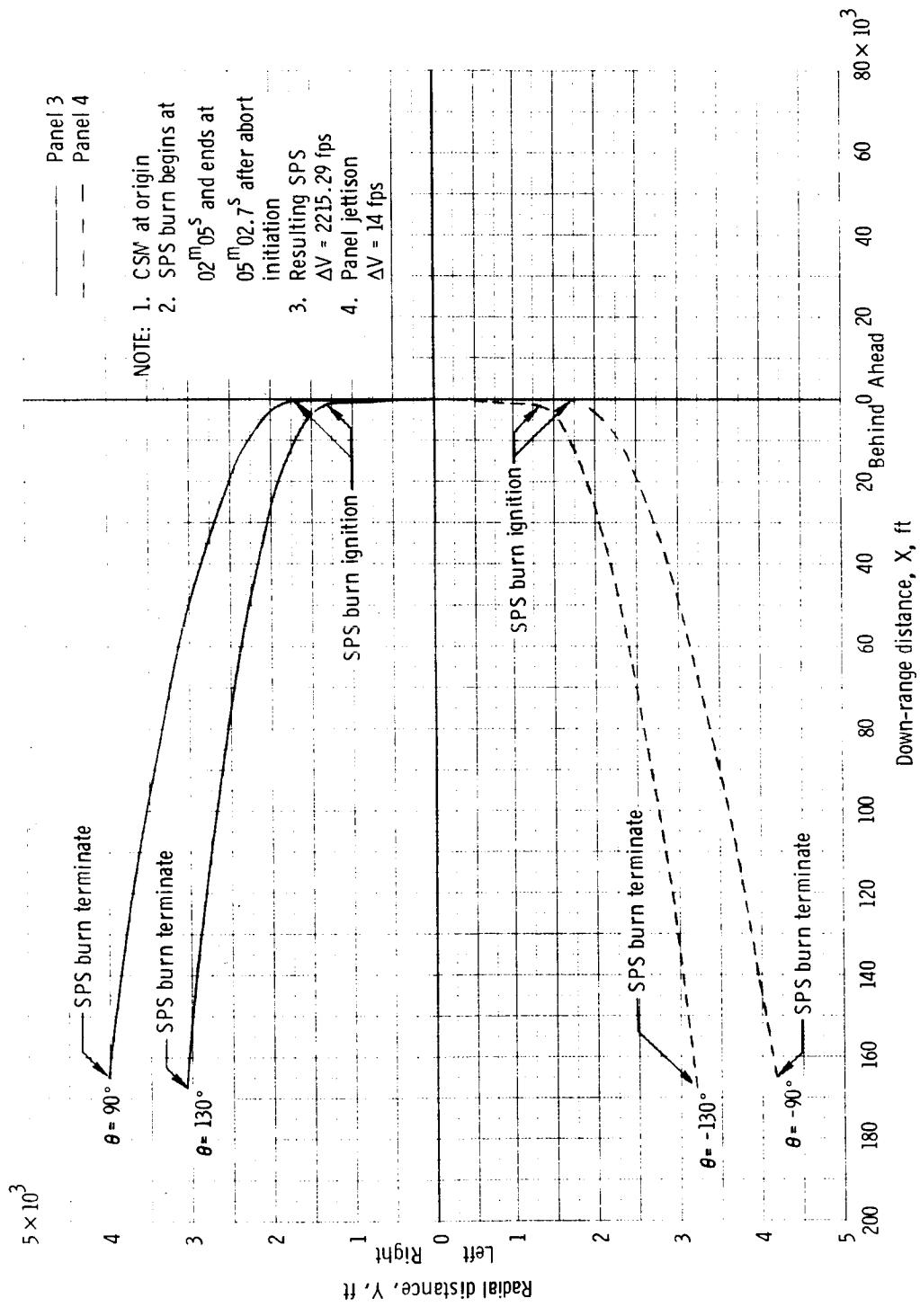
(b) Pitched panels for the middle of mode IV.

Figure 9.- Continued.



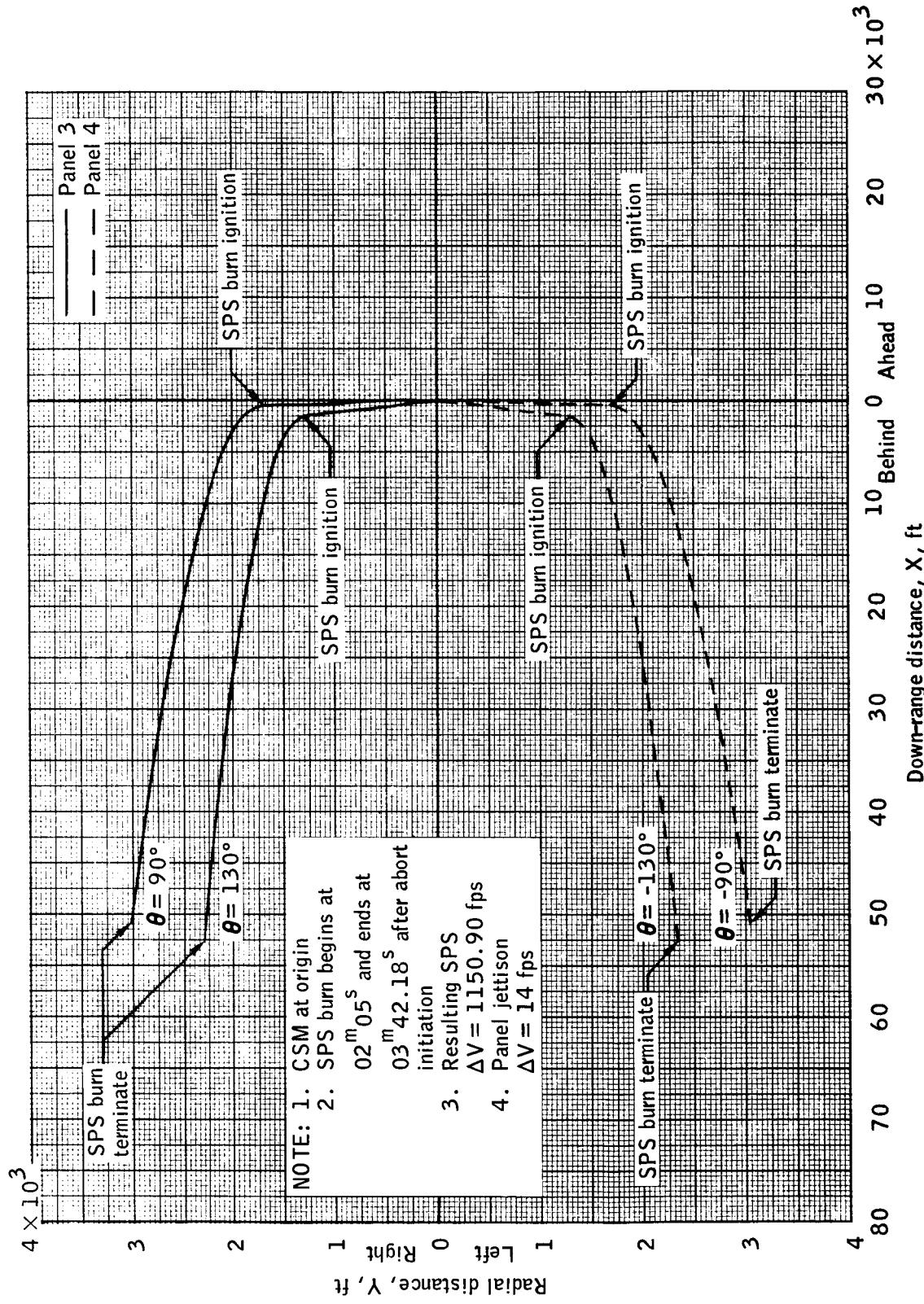
(c) Pitched panels for late mode IV.

Figure 9. - Continued.



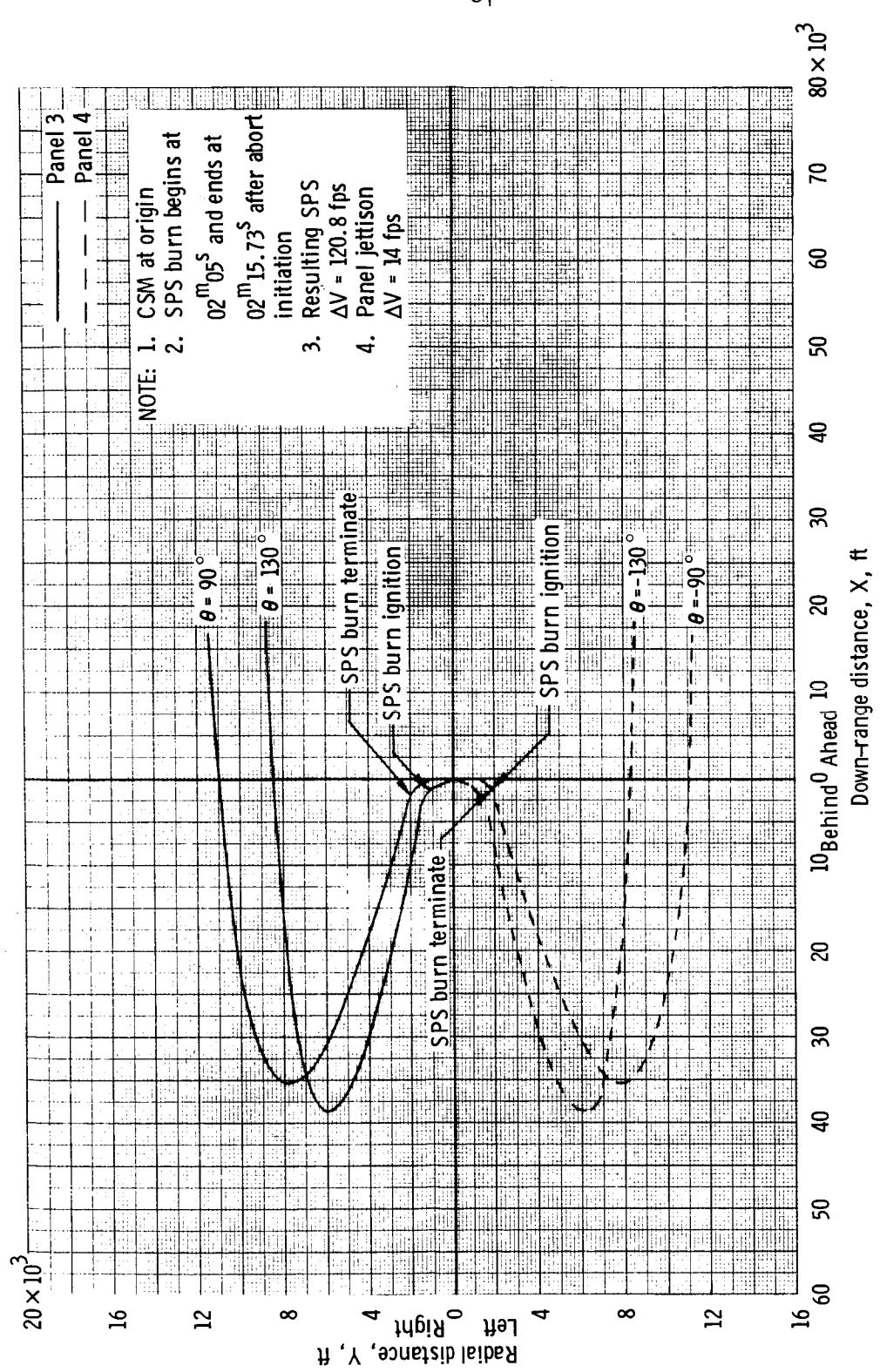
(d) Yawed panels for early mode IV.

Figure 9.- Continued.



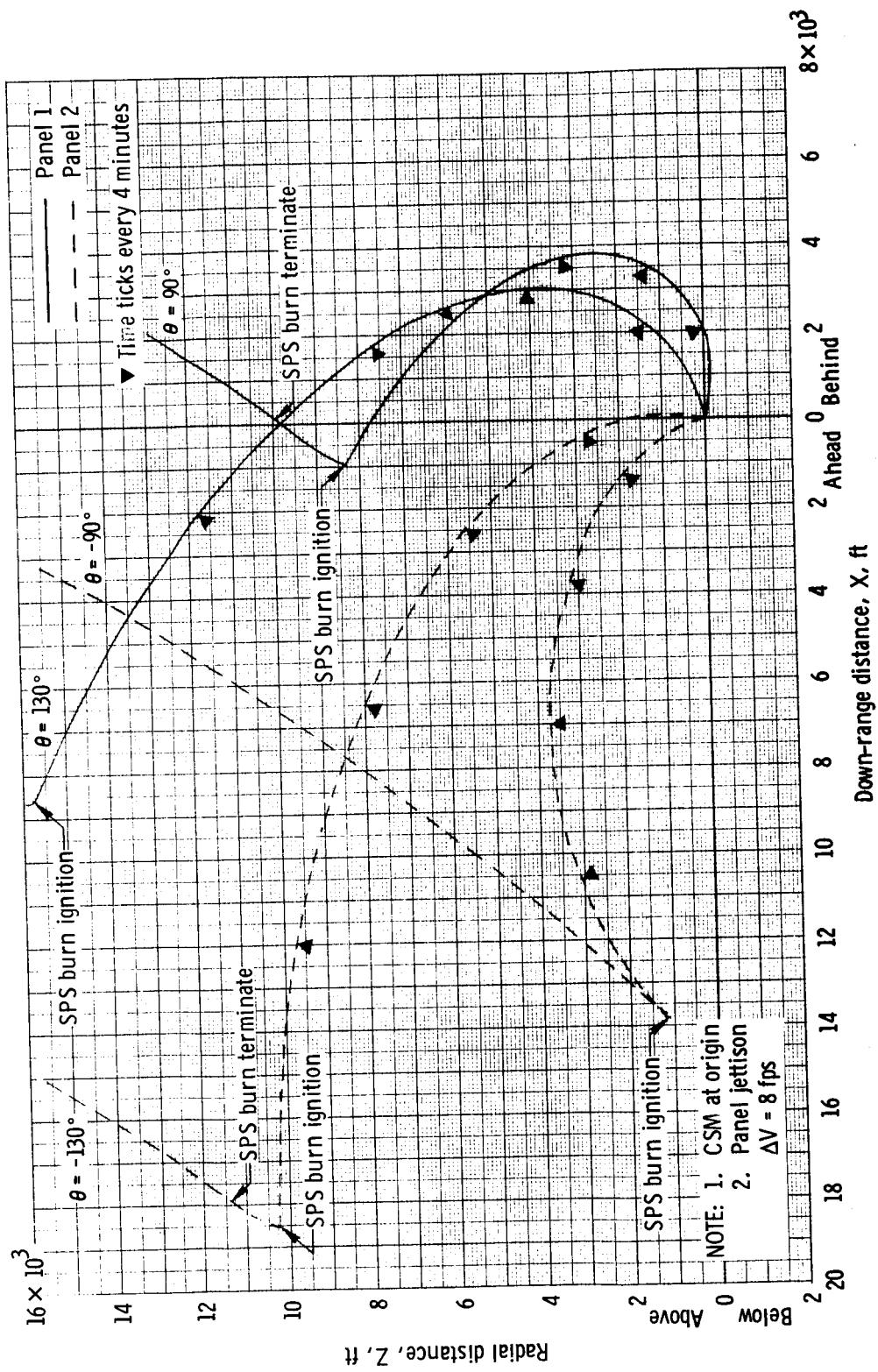
(e) Yawed panels for the middle of mode IV.

Figure 9.- Continued.



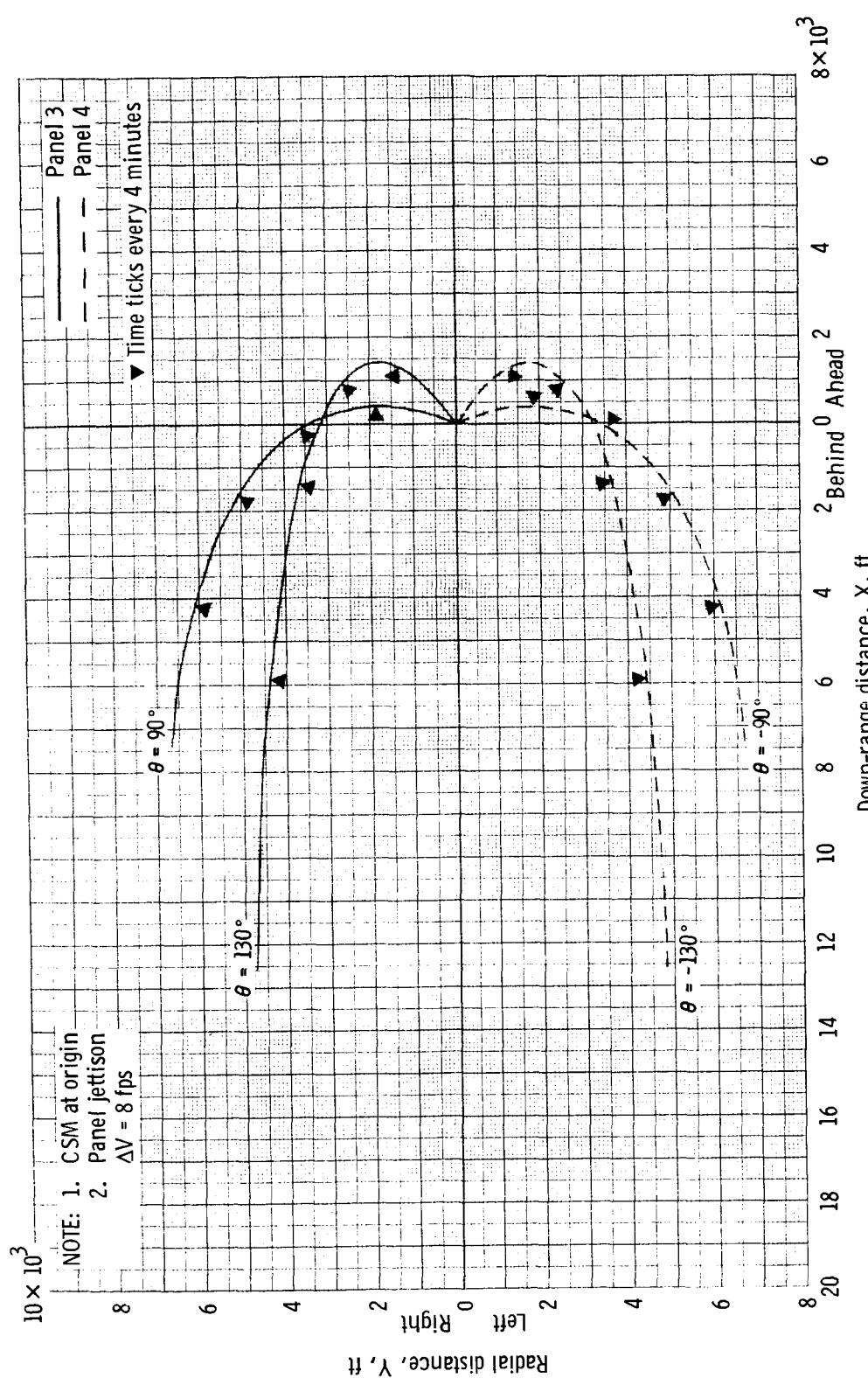
(f) Yawed panels for late mode IV.

Figure 9.- Concluded.



(a) Pitched panels (X-Z plane).

Figure 10. - SLA panels relative motion for orbital aborts initiated in a retrograde attitude, $\Delta V = 8$ fps.



(b) Yawed panels (X-Y plane).

Figure 10.-Concluded.

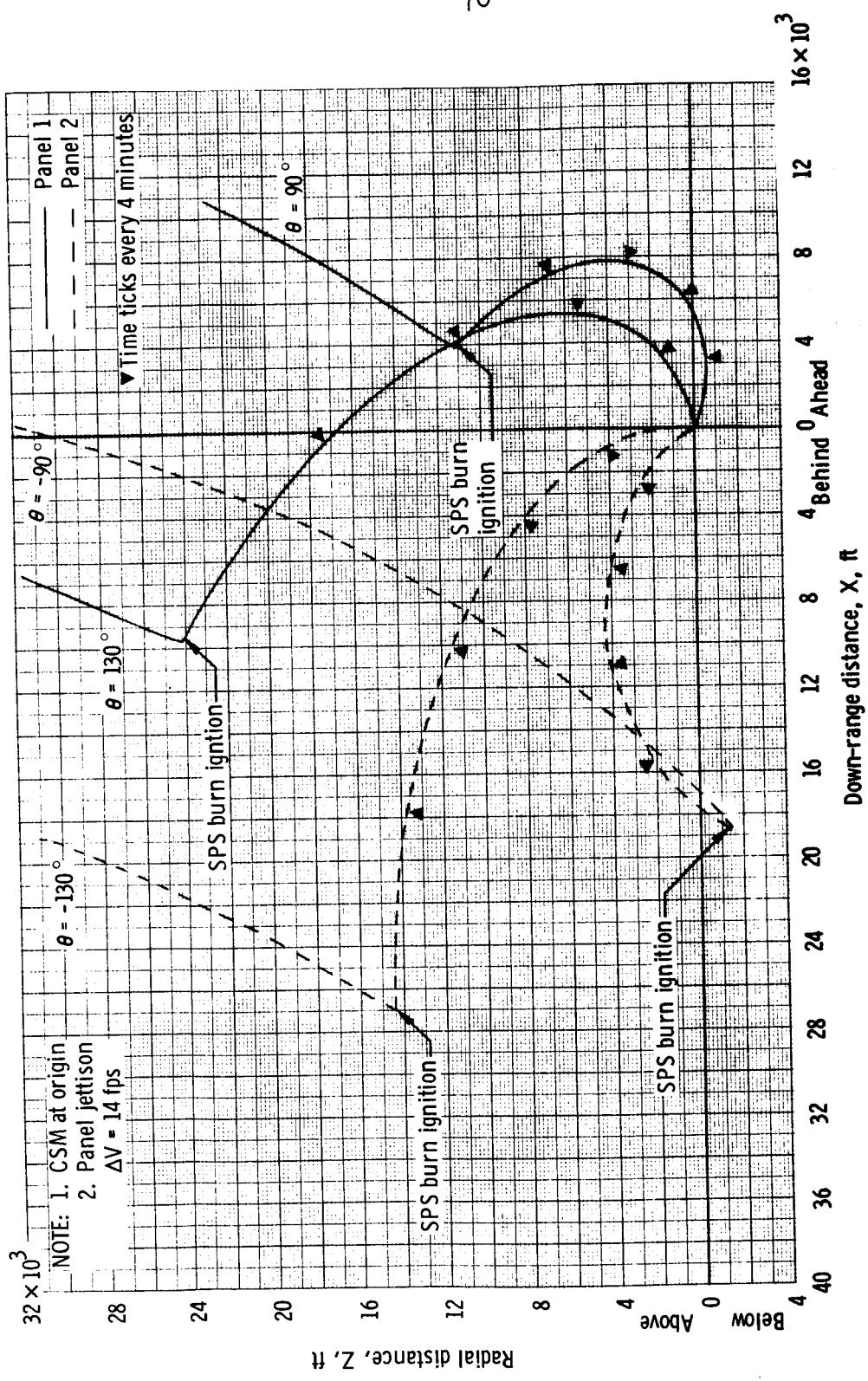
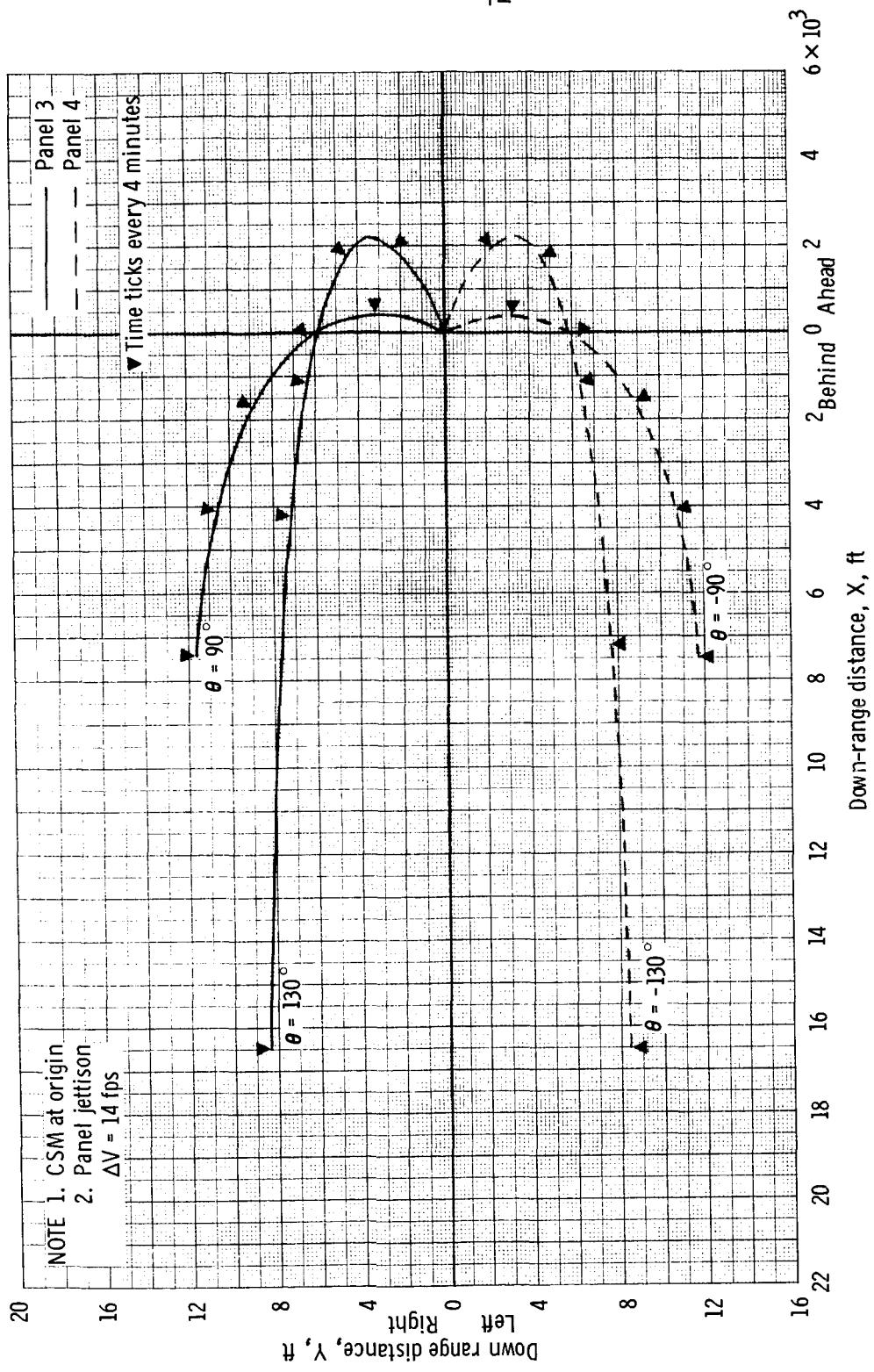
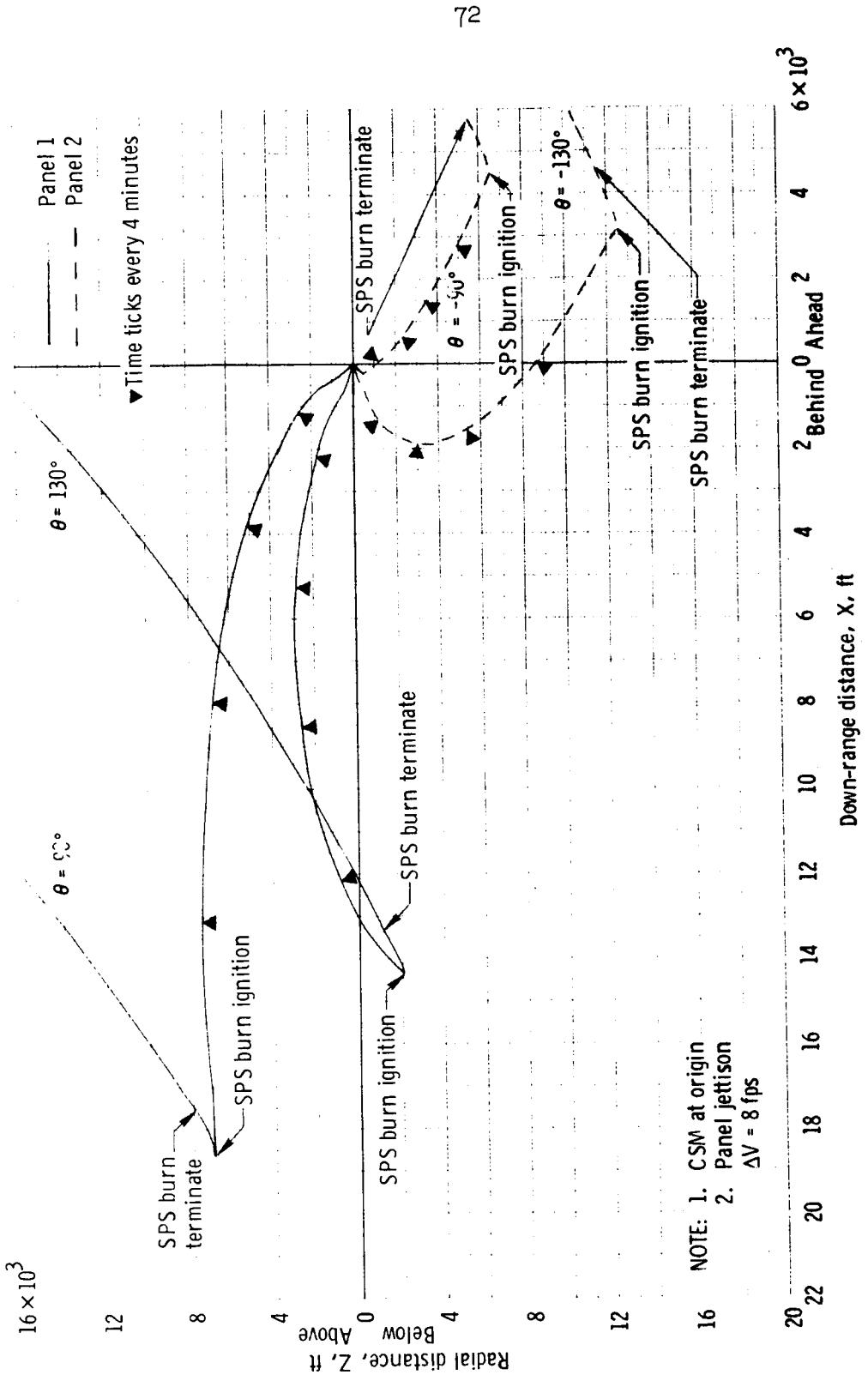


Figure 11. - SLA panels relative motion for orbital abort initiated in retrograde attitude, $\Delta V = 14$ fps.



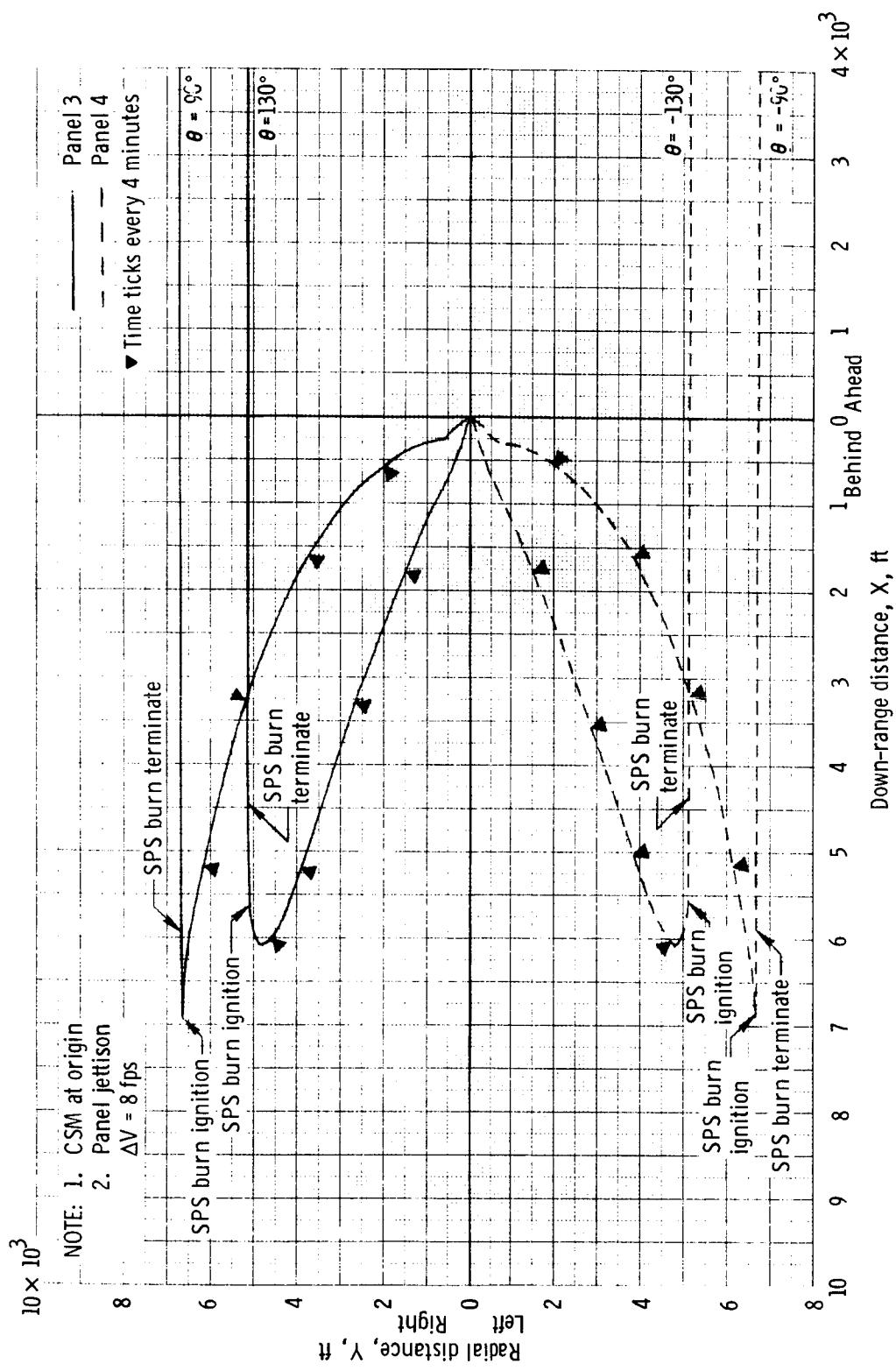
(b) Yawed panels (X-Y plane).

Figure 11. - Concluded.



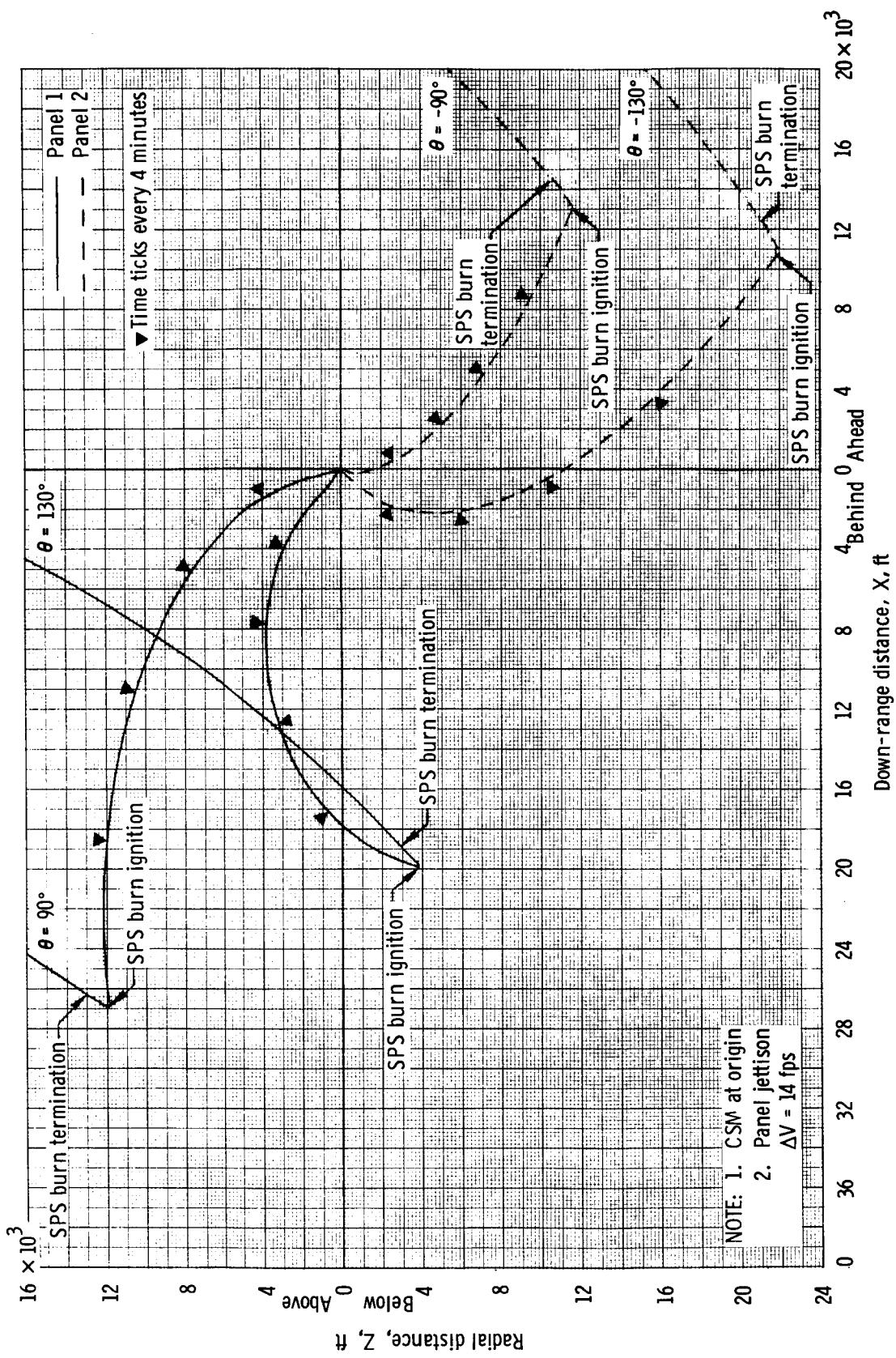
(a) Pitched panels (X-Z plane).

Figure 12. - SLA panels relative motion for orbital aborts initiated in a posigrade direction, $\Delta V = 8 \text{ fps}$.



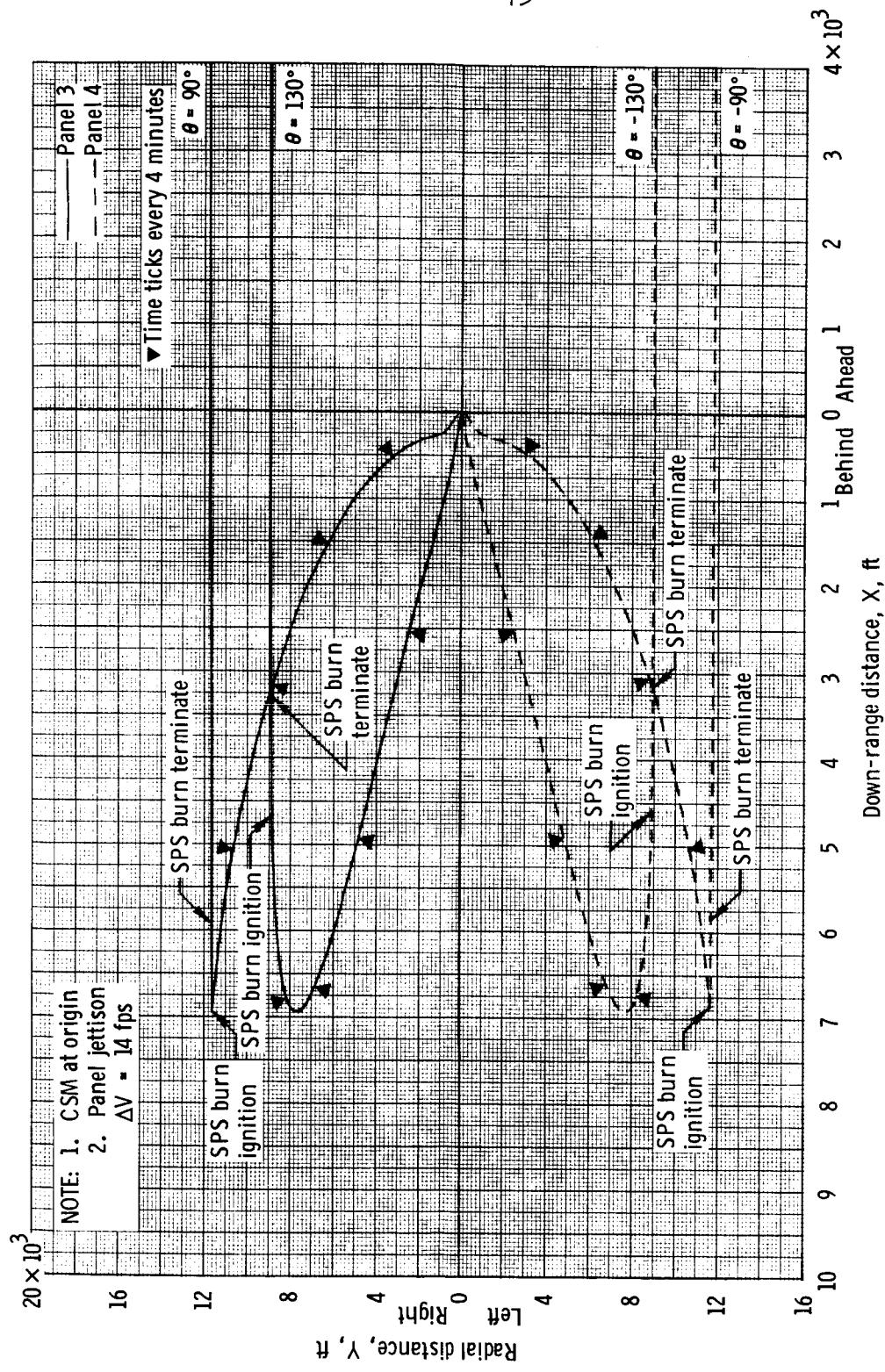
(b) Yawed panels (X-Y plane).

Figure 12. - Concluded.



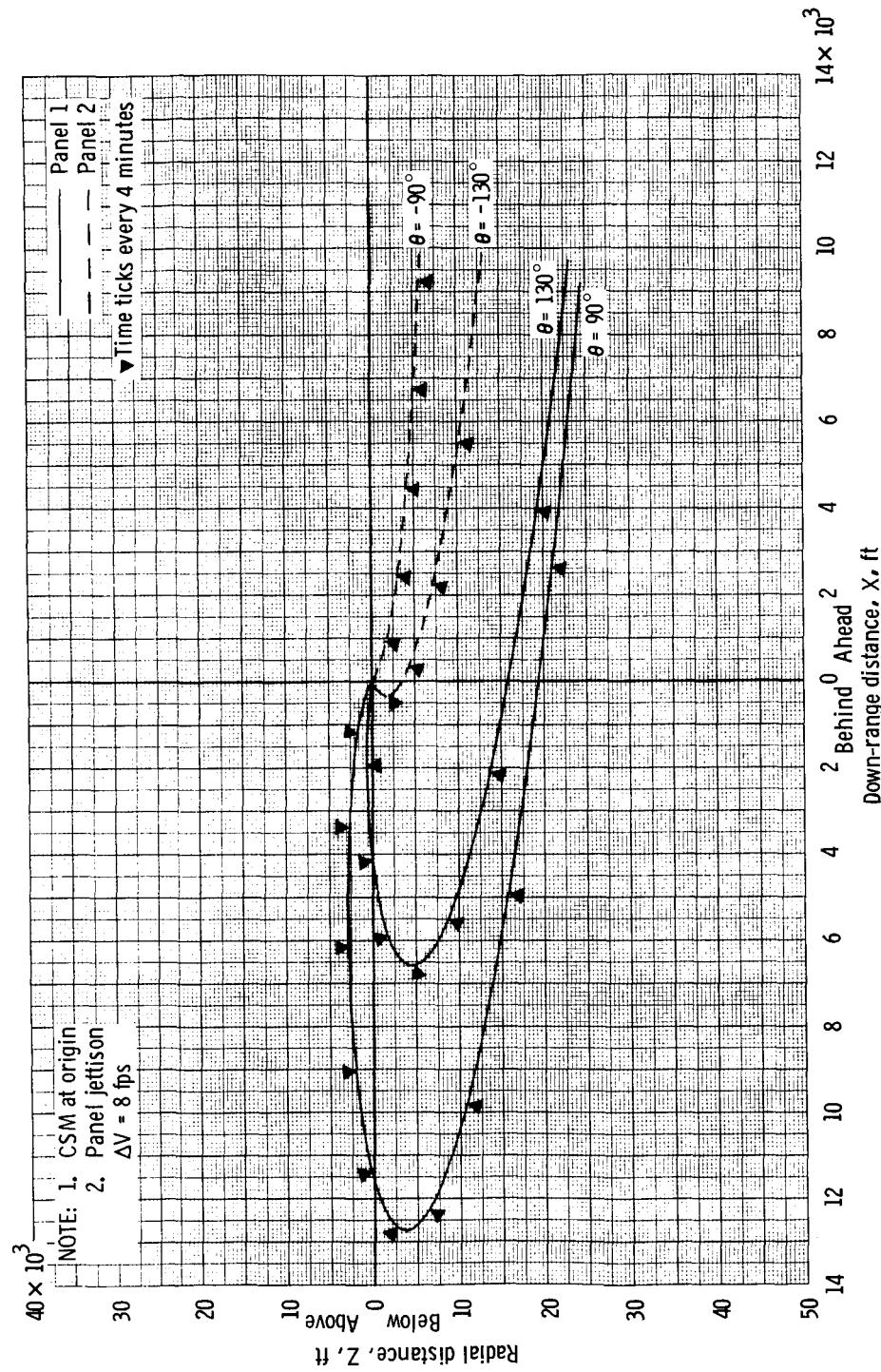
(a) Pitched panels (X-Z plane).

Figure 13.- SLA panels relative motion for orbital aborts initiated in a posigrade direction, $\Delta V = 14$ fps.



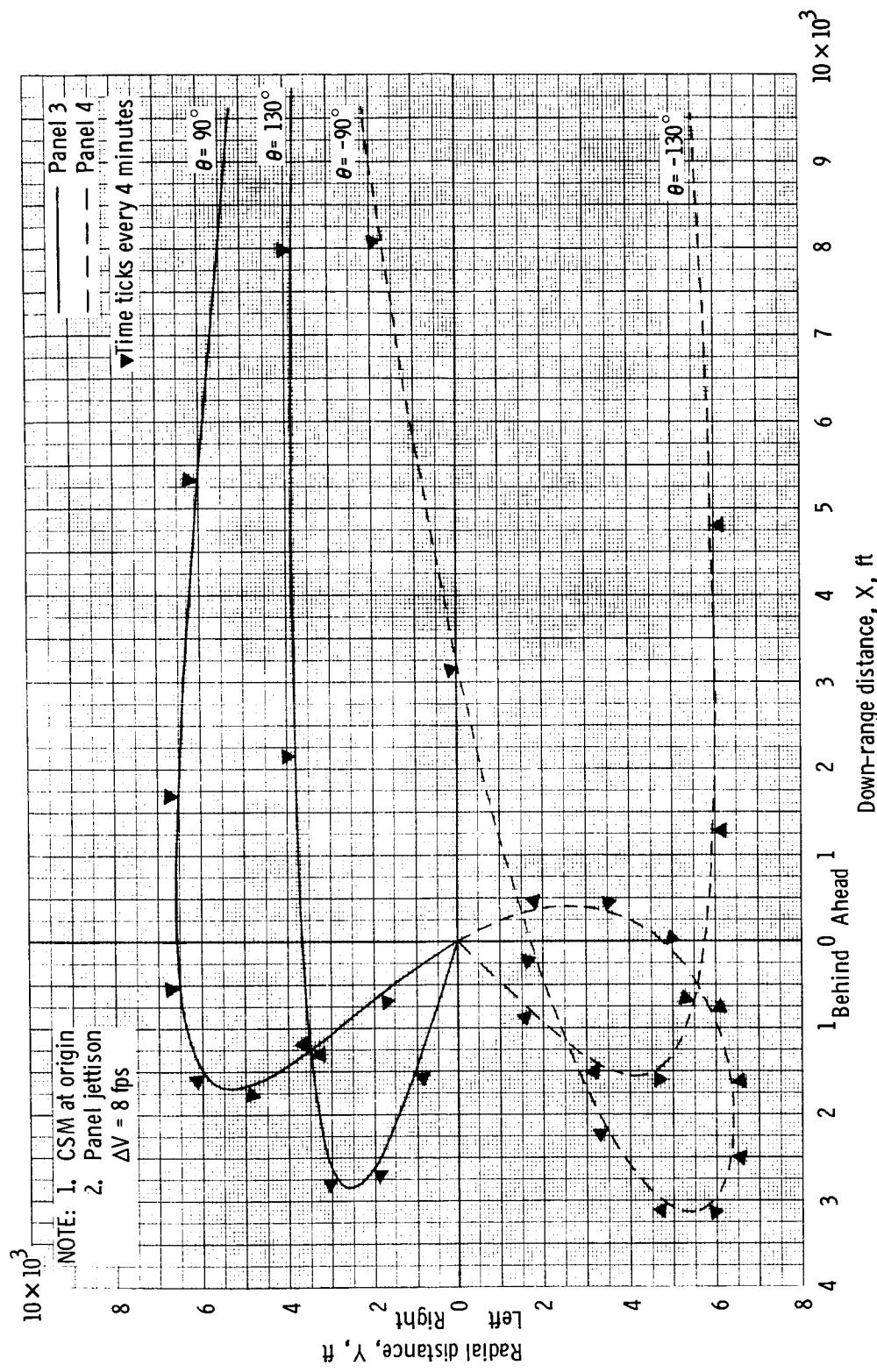
(b) Yawed panels (X-Y plane).

Figure 13.- Concluded.



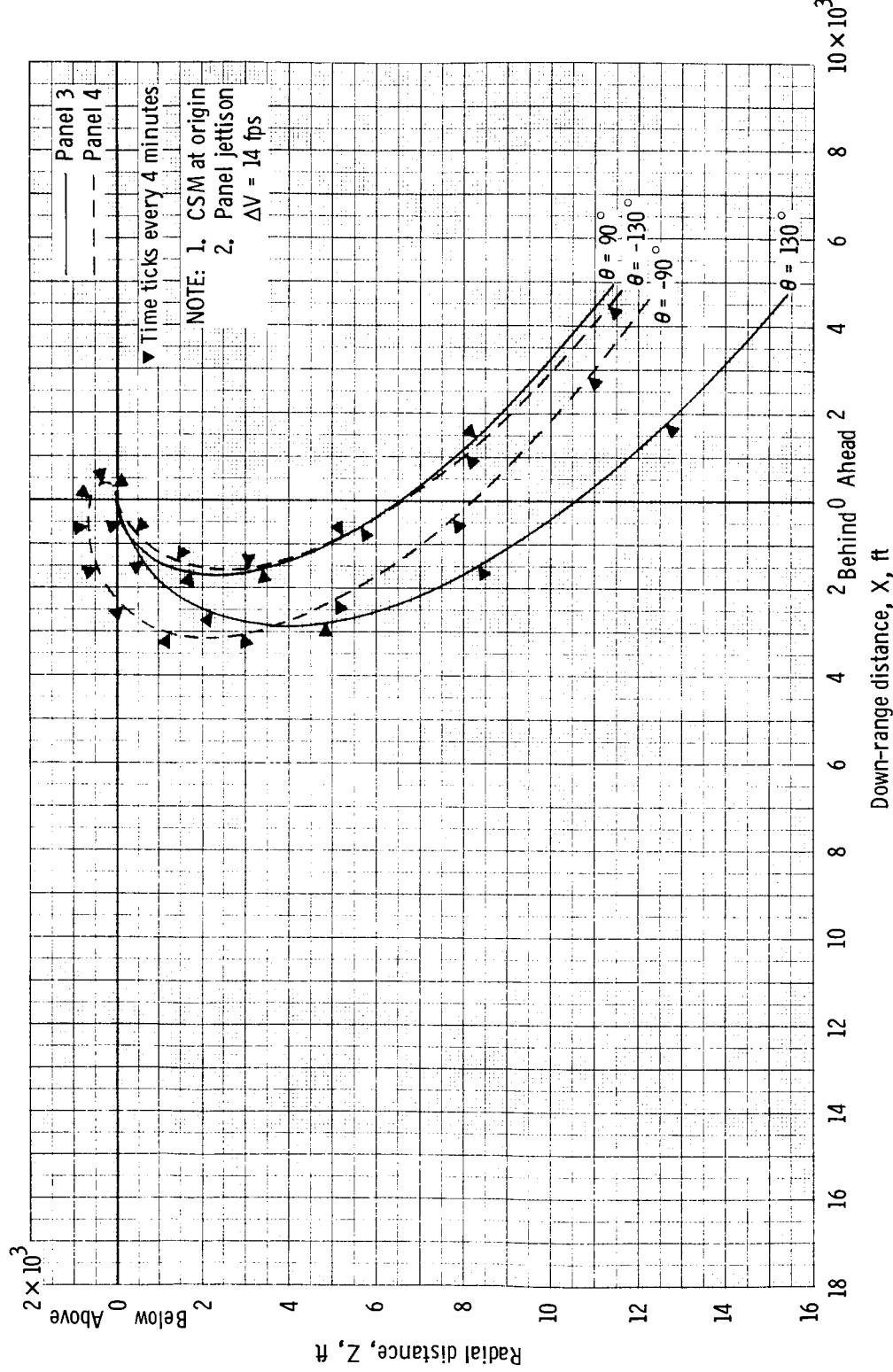
(a) Pitched panels (X-Z plane).

Figure 14.- SLA panels relative motion for nominal CSM/SIVB separation, $\Delta V = 8$ fps.



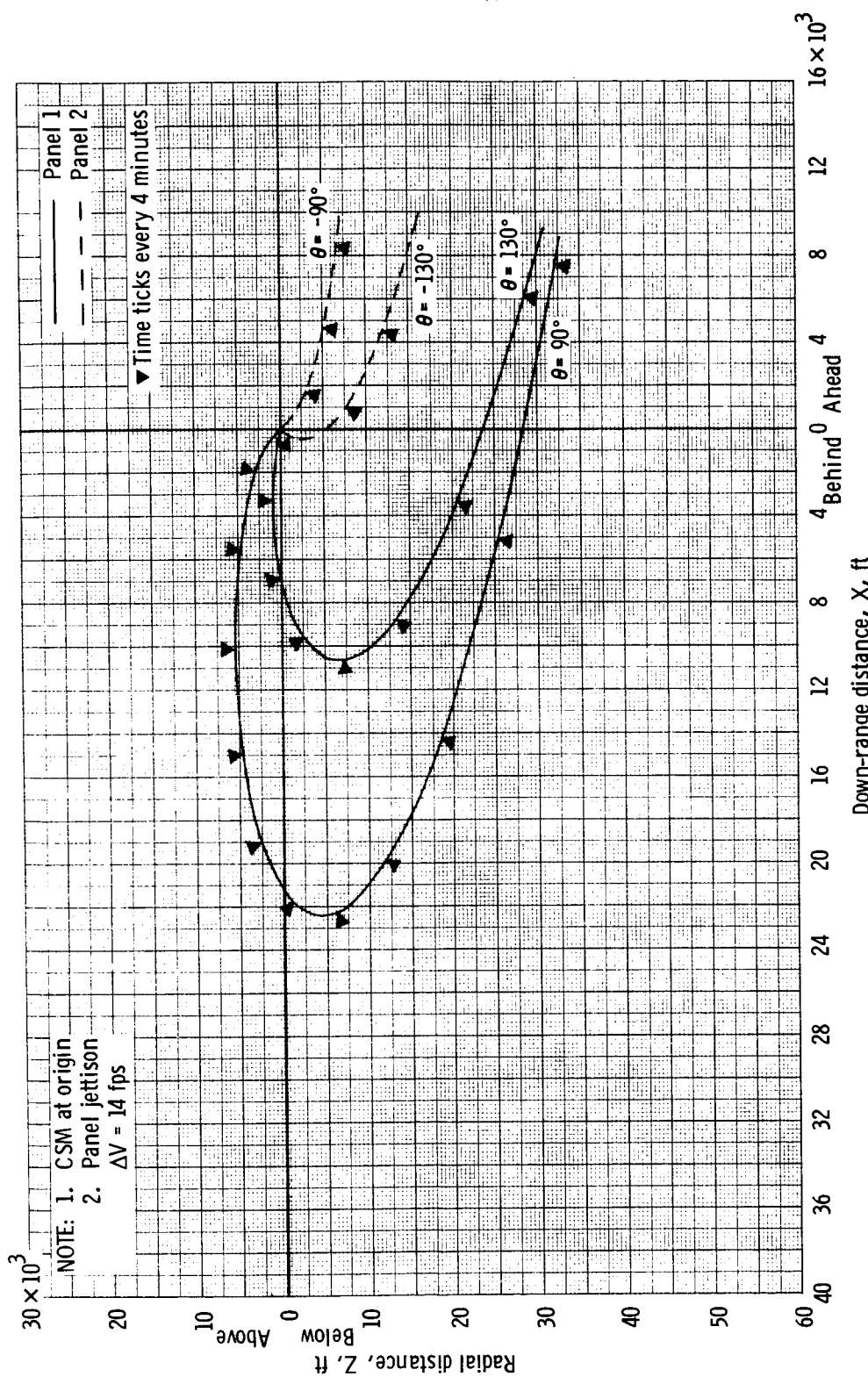
(b) Yawed panels (X-Y plane).

Figure 14.- Continued.



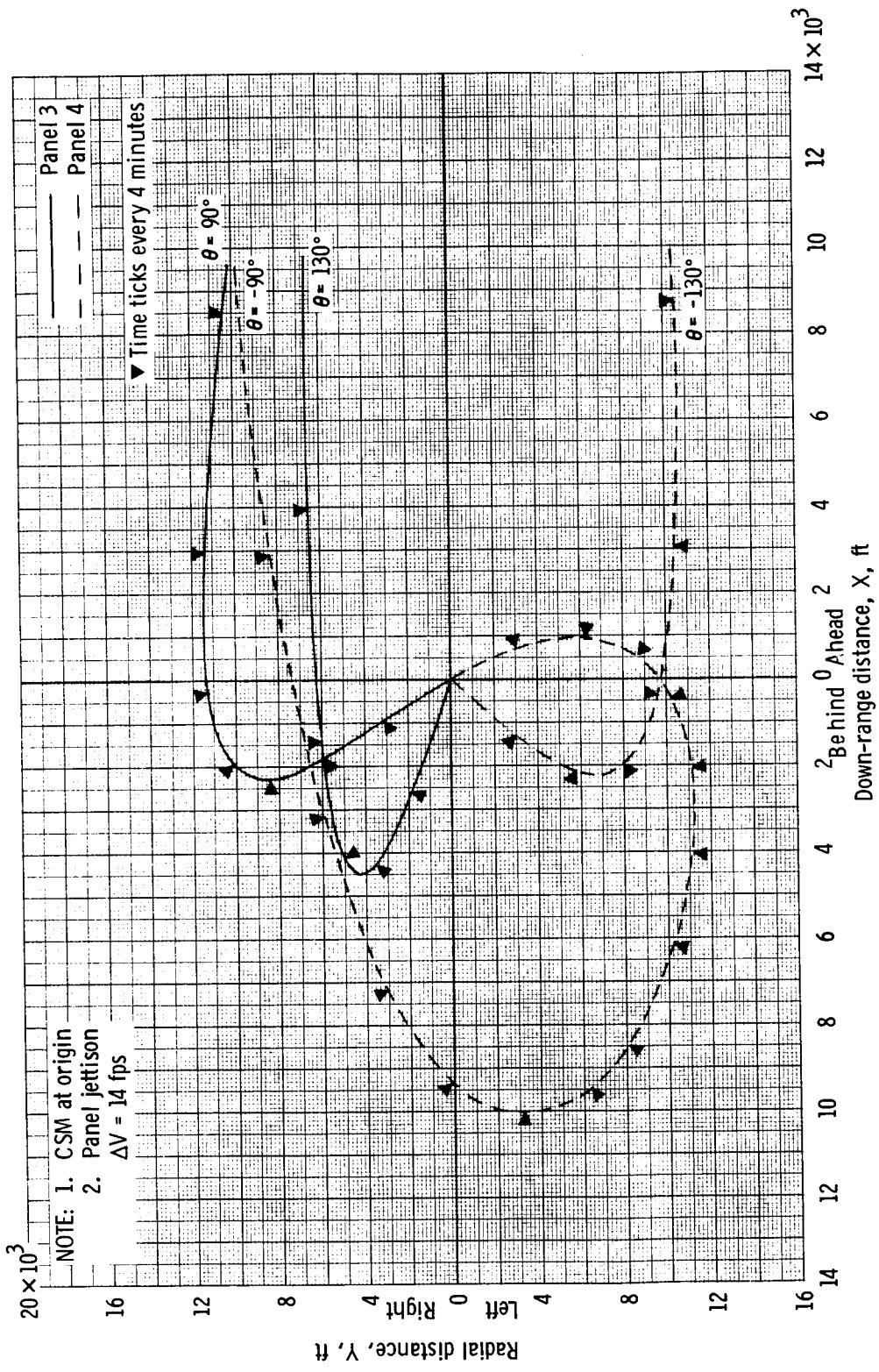
(c) Yawed panels (X-Z plane).

Figure 14.- Concluded.

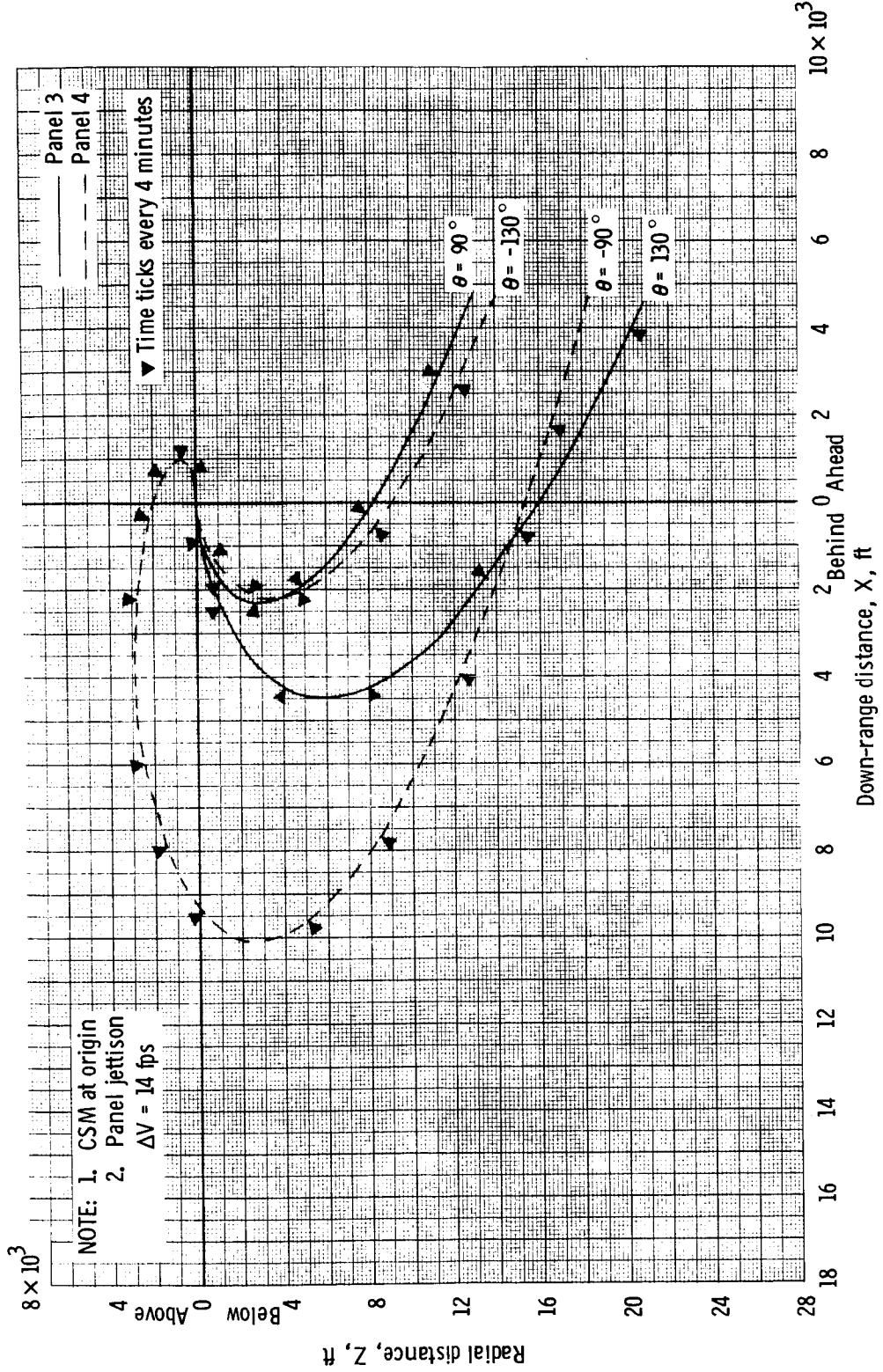


(a) Pitched panels (X-Z plane).

Figure 15. - SLA panels relative motion for nominal CSM/S-IVB separation, $\Delta V = 14$ fps.



(b) Yawed panels (X-Y plane).
Figure 15. - Continued.



(c) Yawed panels (X-Z plane).

Figure 15. - Concluded.

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